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FROM

Board of Health

202

REPORT

OF THE

STATE BOARD OF HEALTH

UPON THE

DISCHARGE OF SEWAGE

INTO

BOSTON HARBOR.

1900.

BOSTON:
WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
18 POST OFFICE SQUARE.
1900.

~~V.6209~~

Eng 1109.00

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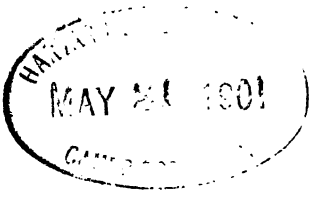

The Board of Health.

Commonwealth of Massachusetts.

OFFICE OF STATE BOARD OF HEALTH,
STATE HOUSE, BOSTON, April 30, 1900.

To the General Court of Massachusetts.

I have the honor to transmit to the Legislature the report required by the provisions of chapter 65 of the Resolves of 1899, entitled "A resolve directing the State Board of Health to report upon the general subject of the discharge of sewage into Boston harbor."

By order of the State Board of Health,

SAML. W. ABBOTT,
Secretary.

REPORT OF THE STATE BOARD OF HEALTH UPON THE GENERAL SUBJECT OF THE DISCHARGE OF SEWAGE INTO BOSTON HARBOR.

To the General Court of Massachusetts.

By chapter 65 of the Resolves of the General Court of Massachusetts of 1899, the State Board of Health is directed to consider the general subject of the discharge of sewage into Boston harbor and the disposal of sewage for the Metropolitan districts of the Commonwealth, and to report a plan for an outlet for a high-level, gravity or other sewer for the relief of the Charles and Neponset River valleys.

Sewage is now discharged into Boston harbor at two points,* one being at the northern limit of the outlet of the harbor near Deer Island Beacon and the other in a more central position nearer the main land on the north side of Moon Island.

At the outlet near Deer Island Beacon, which is four and two-thirds miles from Long Wharf in Boston, and in the northerly edge of the main ship channel, sewage from the North Metropolitan district is allowed to discharge as it comes at all stages of the tide. The quantity of sewage discharged in twenty-four hours now reaches about 50,000,000 gallons; and this quantity, while distinctly visible along the northerly edge of the channel for a half mile toward the city on the incoming tide and toward the sea on the outgoing tide, gradually becomes less distinct at greater distances from the outlet, and disappears entirely within a distance of one and a quarter miles.

With the increase of population in the North Metropolitan district the amount of sewage discharged will increase and will spread over a somewhat larger area; but the Board sees no reason to anticipate any trouble from this for many years in the future upon any inhabitable shores, and believes that the only objection that can be raised to the continual discharge of sewage here will be by those sailing through or near to the stream of sewage within a mile of the outlet.

* See plan opposite title page.

At Moon Island is now discharged sewage from the main drainage works of Boston, including that from the lower valley of Charles River and from a part of Neponset River valley, amounting to a maximum of about 100,000,000 gallons a day.

This outlet is about one and three-quarters miles farther west than the outlet at Deer Island Beacon, and much nearer the main land, and so situated that if sewage were allowed to discharge upon the incoming tide it would be brought to habitable shores and become a nuisance; for this reason the sewage is conveyed to reservoirs on Moon Island during the incoming tide and discharged only during certain hours of outgoing tide, when the currents are most favorable for conveying the sewage-laden water toward the sea through channels which render its passage the least objectionable.

By storing sewage in reservoirs, even for the hours between tides, it becomes more offensive; and the large amount which must be discharged in the short time of favorable outgoing currents renders the locality of the outlet and the surrounding area of a half mile radius much more objectionable than the steady discharge of fresh sewage at Deer Island Beacon. These conditions limit the amount of sewage that may be concentrated at this point without creating a nuisance.

The tunnel connecting Old Harbor Point and Squantum in the line of the Boston main drainage system has a maximum capacity for conveying about 150,000,000 gallons of sewage per day; and this is about the amount of sewage that may be expected forty years hence from the low-level area of Boston for which these works were designed. This amount will be about fifty per cent. more than the present maximum discharge, and in the opinion of the Board this should be regarded as about the maximum amount that can be concentrated at Moon Island outlet without giving unreasonable offence.

We think the Metropolitan Sewerage Commissioners have done well in seeking another outlet for the South Metropolitan system, with the view of ultimately removing from the Moon Island outlet all of the areas now drained which were not contemplated in the original design for the low-lying area of Boston. With the limitation above indicated, we regard the outlet at Moon Island a suitable point of discharge for the sewage of the low-lying portion of Boston.

From a careful study of the channels and currents of the harbor

and of the whole area which may in future be included in the South Metropolitan system, we conclude that the Metropolitan Sewerage Commissioners, in their report upon a high-level gravity sewer, of Feb. 11, 1899, have designated the channel in the harbor best suited to receive the sewage of the South Metropolitan system, viz., the channel along the north-westerly side of Peddock's Island; but after an extended study of the locality we would advise moving the outlets they propose about 2,000 feet further north, so that both will be one mile from Nut Island, one directly north from the middle thereof and the other 1,500 feet more easterly, as indicated upon the plan. Here the sewage will be discharged about 30 feet below the surface at low tide into a strong and deep current, by which it will be kept well away from inhabited shores until it disappears by commingling with enormous quantities of ever-changing salt water.

The paths that will be taken by the sewage discharged at these points with their limitations upon varying conditions of wind and tide are shown upon the maps of the accompanying report of the chief engineer of the Board; and, from a study of the actual conditions existing at the present outlets, we conclude that the sewage of the South Metropolitan system can be discharged at these points continuously without offence except to those who are sailing in the stream of mingled sewage and water, or near its leeward side within a mile of the outlets, and that they are the most suitable points for the discharge of the sewage of the South Metropolitan system.

The plan of outlet designated on pages 77 and 78 of the report of the Metropolitan Sewerage Commissioners of Feb. 11, 1899, to the General Court, with the change of position herein presented, is recommended for adoption by this Board.

In considering the general subject of the disposal of sewage for the Metropolitan districts of the Commonwealth, as required by the resolve, question has arisen as to what areas were intended to be included in this study.

There are areas north and north-east from the North Metropolitan sewerage system which are nearer to Boston than some of the areas which have been considered; but, as the question of discharge of sewage into Boston harbor from these territories is not likely to arise, except for some small areas which may become adjuncts to the North Metropolitan system, for which provision is made under existing laws, no consideration is given to these areas in this report;

but examination has been made of all territory in regard to which may arise question as to whether its sewage had better be discharged into Boston harbor.

After a very complete study of all of the towns of the upper Charles and Neponset River valleys, a brief statement of which is given in the accompanying report of the chief engineer of the Board, it was found that, with few exceptions, to be mentioned, it will be more economical to dispose of the sewage of these towns (which are not designated by law as belonging to one of the Metropolitan districts) by filtration upon land in each town, or by a combination of two or more towns, than by conveying it to Boston harbor.

The exceptions are areas of small extent in the towns of Wellesley, Needham and Weston, lying near to Charles River, the sewage from which can be conveyed across the river and into the Newton main sewer and thence to the Charles River valley sewer of the Metropolitan system.

These are the only additions that it may be well to make in this direction to the South Metropolitan system.

South from Quincy and east from Canton are the towns of Randolph, Holbrook, Braintree, Weymouth and Hingham, whose natural drainage is into Boston harbor. Randolph and Holbrook, when they need to dispose of sewage, can do so economically upon land within their respective territories; but Braintree, Weymouth and Hingham can best discharge their sewage into the sea through the outlets of the high-level sewer. Plans by which this may be accomplished are presented in the report of the chief engineer of the Board.

The change of the outlet herein recommended does not require the presentation of a bill for action by the General Court, because chapter 424 of the Acts of 1899, section 1, provides that no part of said proposed outlet shall be constructed until plans of said outlet shall be further considered by the Metropolitan Sewerage Commissioners and adopted and approved by the State Board of Health.

It is further provided, by section 2 of the same act, after describing the limits of the South Metropolitan system, that "nothing herein shall be construed to vest any rights which cannot be extended to cities and towns or parts thereof other than those herein named, upon such terms and conditions as may hereafter be imposed by legislative enactment," and, as the sections of the towns

of Wellesley, Needham and Weston and the towns of Braintree, Weymouth and Hingham which are not now included in the South Metropolitan system can under this section be admitted into the system when they may in the future need to dispose of their sewage, and they can then be allowed to enter without modification of the works already planned, it does not appear necessary or expedient to prepare a bill at this time under which they may then enter.

HENRY P. WALCOTT,
HIRAM F. MILLS,
FRANK W. DRAPER,
GERARD C. TOBEY,
JAS. W. HULL,
CHAS. H. PORTER,
JULIAN A. MEAD,
State Board of Health.

BOSTON, April 18, 1900.

ENGINEER'S REPORT.

OFFICE OF STATE BOARD OF HEALTH,
STATE HOUSE, BOSTON, April 18, 1900.

To HIRAM F. MILLS, A.M., C.E., *Chairman of Committee on Water Supply and Sewerage of the State Board of Health.*

SIR: — By direction of your committee, I present herewith a report of an investigation relative to a sewage outlet for the relief of the Charles and Neponset River valleys. The investigation has been made under the provisions of chapter 65 of the Resolves of 1899, which is as follows: —

RESOLVE DIRECTING THE STATE BOARD OF HEALTH TO REPORT UPON THE GENERAL SUBJECT OF THE DISCHARGE OF SEWAGE INTO BOSTON HARBOR.

Resolved, That the state board of health is hereby authorized and directed to consider the general subject of the discharge of sewage into Boston harbor and the disposal of sewage for the metropolitan districts of the Commonwealth, and to report a plan or plans for an outlet for a high-level, gravity or other sewer, for the relief of the Charles and Neponset river valleys. Said board may employ such engineering and other assistance and incur such expense as may be necessary to carry out the purposes of this resolve. All bills for expenses incurred by the board under the provisions of this resolve shall be approved by the governor and council before they are sent to the auditor for payment; and in no event shall the expense exceed the sum of ten thousand dollars. The report herein required shall be made to the general court on or before the first day of May in the year nineteen hundred, and if any recommendations are made by the board a bill embodying them shall accompany the report. [*Approved April 28, 1899.*

REPORT.

At the time this resolve was passed there were three Metropolitan sewerage districts under the control of the Commonwealth, as follows: —

1. The North Metropolitan district, which includes all of the cities and towns in the valley of the Mystic River, together with Cambridge, Somerville, Charlestown, East Boston and Winthrop.

2. The Charles River valley district, which includes Waltham, Watertown, Newton, Brighton and Brookline, with a small portion of the Back Bay district of Boston, in the valley of the Charles River.

3. The Neponset River valley district, which includes the towns of Dedham, Hyde Park and Milton, portions of the Dorchester and West Roxbury districts of the city of Boston, and certain areas in Newton and Brookline which are as yet sparsely populated.

The sewage of the North Metropolitan district is disposed of by discharging it into the sea through an outlet at Deer Island Beacon, which is located on the northerly side of the entrance to Boston harbor. The sewage of the Charles and Neponset River valley districts is discharged into the main drainage system of the city of Boston, and flows through the main sewer outlet of that system into the sea at Moon Island on the southerly side of Boston harbor.

DISPOSAL OF SEWAGE OF THE NORTH METROPOLITAN DISTRICT.*

The North Metropolitan system has been constructed in general accordance with a plan prepared by the State Board of Health in 1889, and was intended to provide for the needs of that district as outlined above, so far as they could be foreseen for a period of forty years without material change.

The outlet of this system was selected after very thorough studies and investigations by the Board, the results of which made it evident that sewage discharged continuously at Deer Island Beacon would not reach any shores, nor lodge upon any flats that are exposed at low tide, nor come into the neighborhood of any dwelling or of land that is capable of being used for dwellings in the future, unless it was a portion of Deer Island. The conclusions of the Board as to the disposal of the sewage of the North Metropolitan district were stated as follows: —

As a result of this study, the Board has concluded that it is advisable to construct the sewage works to discharge continuously the comparatively small stream of sewage as it arrives at the outlet. Should the time ever come when such a discharge proves objectionable, and the objection can be removed by holding the sewage back for one, two or three hours after low

* For population of cities and towns in this district, see table on pages 90 and 91.

tide, the capacity of the sewer between East Boston and the outlet will for several years be sufficient to allow of such storage during the hours named; and if it becomes desirable to store the sewage through the incoming tide and discharge it only when the outgoing tide will carry it directly to sea, a reservoir can be then built on Deer Island as well as at the present time; but the Board does not anticipate the need of such a reservoir.

The results of the discharge of sewage at this place during the time that the works have been in operation bear out the conclusions that were reached by the Board in its studies in 1889. Investigations made by the Metropolitan Sewerage Commission in 1898, at a time when the average quantity of sewage flowing from the outlet amounted to about 42,000,000 gallons per day, showed that sewage could be traced for a distance of only about a mile from the outlet on the incoming tide, and for about one and one-eighth miles from the outlet on the outgoing tide, and these results have been confirmed by further investigations made recently by the State Board of Health. The sewage is discharged into a strong current reversed four times daily, and no collection or deposit of sewage matter accumulates anywhere. The sewage brought to this outlet is disposed of completely, so that its presence can nowhere be detected an hour and a half after its arrival. It is discharged at a place remote from inhabited shores, and is traceable at the present time only for a distance of about a mile in the direction of the city on the incoming tide, and when the tide turns it is carried to sea and dispersed within a distance of a little over a mile. It is not possible to secure an equally complete and satisfactory disposal of this sewage in any other way, unless at a much greater expense, and no change in the method of disposing of this sewage seems necessary or desirable at the present time.

THE BOSTON MAIN DRAINAGE SYSTEM AND THE METROPOLITAN DISTRICTS CONNECTED THEREWITH.

The Boston main drainage works, into which the sewage of the Charles and Neponset River valley Metropolitan sewerage districts is at present discharged, were designed to intercept the dry-weather flow of sewage from the sewers in the portion of the city south of Charles River which formerly discharged their entire contents into the various waters about the city, and to pump it to the outlet at Moon Island.

The area considered in designing the main drainage works was the territory fronting on Boston harbor, bounded by Charles River, Mother Brook and the Neponset River, and included the portion of the city of Boston south of Charles River, all of the town of Brookline and city of Newton, and portions of Waltham, Watertown, Dedham and Hyde Park. The total area of this territory is 58 square miles.

It was a part of the original plan to convey the sewage of the higher portions of this territory to the Moon Island outlet by means of a so-called high-level intercepting sewer, which should operate by gravity alone, without the need of pumping, and which should receive the sewage of most of the portions of the territory described which are above grade 40, embracing an area of about 46 square miles, and leaving about 12 square miles tributary to the pumping station of the main drainage system. Very little of the territory which would naturally be served by a high-level sewer was so densely populated as to require sewerage at the time the main drainage works were built; and, in order to avoid the necessity of constructing a high-level sewer in the near future, the low-level system was designed and constructed of liberal capacity to meet the requirements of both the low-level and high-level areas for many years, and to serve ultimately an area of 15 square miles after the high-level sewer had been built.

The sewers of the city were built upon the combined plan, and were intended to remove both sewage and storm water. In the design of the main drainage works provision was made for taking the dry-weather flow of the sewers and in addition a portion of the surface water from storms or melting snow, amounting to one-fourth of an inch in depth upon the area in twenty-four hours; but any surplus of flow at times of storms that could not be received into the intercepting sewers was to be allowed to discharge at the old outlets of the sewers.

While in designing the works it was assumed that the storm water to be received into the main drainage system was to be a uniform amount from all parts of the area sewered, it appears that it was then the intention to favor certain low districts, where the cellars were liable to be flooded during heavy rains at a time of high tide, by receiving a greater proportion of the rainfall upon these districts into the main drainage system; and it appears that the

works as now operated receive the storm water from four separate areas in much larger quantity than was provided for in the general design of the works.

The main drainage works were completed in 1884. They consist of a main sewer, beginning at the junction of Huntington Avenue and Gainsborough Street in Boston, and extending in a generally easterly direction across the city to a pumping station at old Harbor Point, on the shore of Dorchester Bay. Here the sewage is raised about 35 feet and discharged into a tunnel 7.5 feet in diameter, through which it passes under Dorchester Bay to Squantum, and then flows through an outfall sewer to the reservoirs at Moon Island, from which it is discharged on the outgoing tide. A sewer beginning near the Charles River Bridge, at the extreme northerly end of the city, follows approximately the shore of the Charles River and conveys the sewage of the westerly side of the city to the head of the main sewer at Huntington Avenue and Gainsborough Street; and a corresponding sewer on the easterly side of the city intercepts the sewage along the harbor front and along Fort Point Channel and South Bay, and discharges it into the main sewer at the place where it crosses Albany Street. The sewage of Roxbury, West Roxbury, South Boston, Dorchester and other localities is discharged into the main sewer at various points.

In 1892 the main sewer of the Charles River valley Metropolitan district was completed and connected with the main sewer of the main drainage system at Huntington Avenue and Gainsborough Street; and since that time the sewage of Waltham, Watertown, Newton and Brookline and of the Brighton district and portions of the Back Bay district of Boston has been discharged into the main drainage system, the metropolitan district paying rent to the city of Boston for the use of that system.

The Charles River valley Metropolitan district includes the portions of Waltham and Watertown which are situated north of Charles River and which were not included in fixing the capacity of the main drainage system.

In 1895 the Neponset River valley Metropolitan district was created, and the main sewer of this district was subsequently connected with the Dorchester intercepting sewer of the city of Boston, which discharges into the main sewer of the Boston main drainage system a short distance above the pumping station. The Neponset

valley Metropolitan district includes the town of Milton and portions of the towns of Hyde Park and Dedham south of the Neponset River and Mother Brook which were not included in determining the capacity of the main drainage works. In building the Neponset valley Metropolitan sewer it was assumed that the high-level sewer proposed in the original design of the main drainage system would eventually receive the flow of that sewer above a point in the neighborhood of the boundary line between Dorchester and Hyde Park, near the Neponset River; and, while above this point the Neponset valley sewer is of sufficient size to serve the district for many years, its size below the place where the high-level sewer is expected to cross is only sufficient for a limited time, and provision for relieving it must soon be made.

In 1898 the city of Boston made a contract with the city of Quincy by which the sewage of that city is discharged into the outfall works of the Boston main drainage system at Squantum.

The Capacity of the Boston Main Drainage Works when developed.

The Dorchester Bay tunnel would be the most troublesome and expensive portion of the Boston main drainage works to duplicate, and the capacity of this tunnel may be regarded as the practical limit of the enlargement of the present main drainage works. The capacity of the tunnel was considered in 1889 by Mr. F. P. Stearns, chief engineer of the Board, who reports his conclusions as follows: —

The tunnel under Dorchester Bay has a brick lining, and its section is circular, 7.5 feet in diameter. Its flowing capacity depends upon the difference in level of the surfaces of the sewage in the chambers at its ends. The height of the sewage in the chamber at the lower end varies with the height in the reservoir at Moon Island; consequently, the flowing capacity of the tunnel will be least when the reservoir is full.

When the reservoir is full and the deposit sewers at the upper end of the tunnel are also full, the sewage at the upper end of the tunnel will be 5.38 feet higher than at the lower end, and under these conditions the tunnel will carry 122,000,000 gallons per day. If, with the same conditions at the lower end, the sewage in the chamber at the upper end of the tunnel is allowed to rise higher, the carrying capacity of the tunnel will be increased. If allowed to rise to within one foot of the surface of the ground

around the chamber, the quantity carried will be 166,000,000 gallons per day. It will be feasible to raise the sewage in this chamber considerably above the top of the deposit sewers, but not to the extreme height above mentioned. Taking into consideration these facts, and that the tunnel would convey larger volumes when the reservoir was not full, the conclusion has been reached that the maximum capacity of the tunnel is 154,000,000 gallons per day, a volume which coincides with that for which the works were designed.

The capacity of the works for pumping the sewage is being enlarged at the present time, and can be made adequate to pump all of the sewage that the tunnel will carry without special difficulty.

The outfall sewer from the lower end of the tunnel to the reservoirs at Moon Island is of much greater capacity than the tunnel. At the end of last year the work of enlarging the sewage reservoirs at Moon Island was completed, and the capacity of the reservoirs now in use is 43,500,000 gallons. The discharge sewers were designed of sufficient capacity in the beginning to provide sufficiently for the discharge of the sewage from the reservoirs at the most favorable portion of the tide, after the capacity of the reservoirs had been enlarged. With the present reservoir capacity it is practicable to receive sewage at the rate of 100,000,000 gallons per day and discharge it only during the second and third hours of the outgoing tide, or, if the discharge is continued for four hours and sewage is stored for only about eight hours, sewage can be received and disposed of at the rate of 122,000,000 gallons per day. It is possible to enlarge somewhat further the capacity of the reservoirs if found desirable.

The area included in the Boston main drainage district and the two Metropolitan sewerage districts which discharge sewage into the main drainage system, together with the area of the city of Quincy, is about 121 square miles. The total population of this territory at the present time is about 603,000. A portion of this territory in the outlying towns and cities is not densely populated and not yet provided with sewers, and in a very few of the more densely populated areas, such as in the town of Dedham, sewers have not yet been provided. It was estimated by the Metropolitan Sewerage Commissioners, in 1897, that a population of about 514,270 was connected with the main drainage works and the tributary Metropolitan sewers at that time.

In the areas forming a part of the main drainage system, aside from the Metropolitan districts, the sewers are practically all constructed upon the combined plan, and receive both sewage and storm water. The sewers of the town of Brookline and of the Brighton and Back Bay districts of Boston, which form a part of the Charles River valley Metropolitan district, are also provided very largely with sewers constructed on the combined plan; but the sewers in Newton, Waltham and Watertown, in the Charles River valley, and the sewers connected with the Neponset valley sewer, are constructed to receive sewage only, excepting one or two very small districts in Dorchester, and storm water is excluded from the sewers. In some cases also, notably in Newton, drains are provided to lower the ground water and reduce the leakage into sewers connected with the Metropolitan system.

The areas of the various districts which dispose of their sewage into the Boston main drainage system and the areas served by combined systems of sewers in these districts are as follows: —

	Square Miles.
Area tributary to the Charles River valley Metropolitan sewer,	42.0
Area tributary to the Neponset valley Metropolitan sewer,	44.0
Area tributary to sewers of the city of Quincy,	12.0
Area tributary directly to Boston main drainage works, exclusive of above,	23.0
Total area connected with main drainage works,	121.0
Area served by combined systems tributary to the Charles River valley sewer,	6.9
Area served by combined systems tributary to the Neponset River valley sewer,	.7
Area served by combined systems tributary to the Boston main drainage system, exclusive of above,	23.0
Total area served by combined systems connected with the main drainage works,	30.6

The quantity of sewage discharged from the Boston main drainage system in recent years is shown approximately by the records of the operation of the pumps at the pumping station. These records do not show accurately the quantity of sewage pumped, on account of the slip of the pumps, but an estimate of the loss caused in this way has been made from observations of the flow, and the records, with those corrections, are probably fairly reliable. From these

records a table has been prepared of the quantity of sewage pumped on days when the quantity was not increased by rain or melted snow, to show the probable dry-weather flow of sewage from the works at present.

The results show that the maximum flow of sewage on days when the flow is not increased by rain or melting snow, that is, the maximum dry-weather flow, from the main drainage system is about 90,000,000 gallons per day. The capacity of the works as at present developed is about 122,000,000 gallons per day, so that the quantity of rainfall that can be received into the sewers at times of maximum flow of sewage amounts to about 32,000,000 gallons per day. This is equivalent to a rainfall of about .06 of an inch in twenty-four hours over the 30.6 square miles of combined sewers connected with the works at present. The average dry-weather flow of sewage from the Boston main drainage works, however, is in the vicinity of 75,000,000 gallons, leaving a capacity of 47,000,000 gallons for rainfall at the present time. This would amount to .09 of an inch in twenty-four hours over the 30.6 square miles of combined sewers tributary to the Boston main drainage system. If the works should be made capable of disposing of 154,000,000 gallons per twenty-four hours, there would remain a capacity of 79,000,000 gallons, which would represent the quantity of storm water in addition to the dry-weather flow of sewage that could be received and disposed of during each day at the present time. This quantity would be equivalent to a rain fall of .15 of an inch per day, or .006 of an inch per hour over the 30.6 square miles of combined sewers connected with the main drainage system.

At the present time, as already indicated, there are four districts from which all of the rain water that can pass into the main sewers through the connections provided for these districts is admitted to those sewers. Three of the districts are on the easterly side of the city, and join the main sewer at Beach Street, Dover Street and Dedham Street, respectively. The fourth is known as the Church Street district, and connects with the west side intercepting sewer in Beacon Street near the Public Garden. There is a regulator on the east side sewer above Beach Street, by which the flow of sewage through the east side intercepting sewer is shut off when the sewage rises above a certain height in that sewer, and the sewage from

tributary sewers above this point discharges with the storm water at the overflow outlets. Similarly, on the west side intercepting sewer there is an automatic shut-off at Charles and Cambridge streets, which shuts off the flow of sewage at this point at times of storm when the main sewer fills above a certain height, and the sewage and storm water from tributary systems above this point discharge into Charles River. All other connections with the main drainage system, excepting the four mentioned, are provided with automatic regulators which shut off the flow from tributary sewers into the main intercepting sewers at times of storm when the sewage in the intercepting sewers rises above a certain height; and under these conditions the full capacity of the works is devoted to removing the sewage and storm water from the four areas referred to, with such other sewage and storm water as may leak into the main sewers through regulators and otherwise.

The quantity of mingled sewage and rain water that can flow through these unregulated connections with the east side and west side sewers is probably not sufficient to fill those sewers unless in exceptionally heavy rains.

It will be seen, then, that when rain or melting snow begins to increase the flow in the common sewers, all of the water mingled with the sewage enters the main drainage system until the main drainage sewers are filled to the height at which the regulators are set to close; then, if the flow of rain water into the tributary sewers continues, the regulators close automatically, and very nearly all of the mingled sewage and storm water from all tributary districts, excepting the four districts already referred to, discharges into the waters about the city through overflow outlets, and the pumping system is then devoted to removing the mingled sewage and storm water from the four districts connected with the main sewer system without regulators, together probably with a very little of the mingled sewage and storm water from other districts, until the flow of rain water subsides.

The quantity of rain water that can be received from tributary districts provided with combined sewers is already less than was intended to be received when the works were constructed; and, as the quantity of the ordinary flow of sewage in the main drainage and tributary systems increases with the growth of population in the districts which these systems now serve, the capacity of the

main drainage system for removing storm water, except from the four districts referred to, will decrease, and unless some relief is provided, overflows will occur with smaller rains and thaws and increase in frequency and duration, thus tending to defeat the object for which the works were built, viz., to prevent the pollution of the waters about the city.

NECESSITY FOR RELIEVING THE BOSTON MAIN DRAINAGE SYSTEM.

Estimated Future Population of the Main Drainage District and Metropolitan Districts connected therewith, and Probable Quantity of Sewage that will flow from these Districts.

The probable growth of the population in the Boston main drainage district and the tributary Metropolitan areas has been estimated from the indications furnished by the past growth of the various municipalities in these districts. The total habitable area of each of the cities and towns of the districts and of the principal divisions of the city of Boston has been ascertained, and this area has been taken into consideration in estimating the future population of these districts.

The population of each of the cities and towns included in these districts for the last fifty years, together with the estimated future population of each up to 1940, may be found in a table on pages 90 and 91. The estimated total future population in these districts is given in the following table: —

Estimated Future Population of the Main Drainage District and the Metropolitan Districts connected therewith.

Year.	Estimated Population.	Year.	Estimated Population.
1900,	602,500	1925,	1,137,400
1905,	695,000	1930,	1,267,000
1910,	795,300	1935,	1,400,200
1915,	902,200	1940,	1,539,000
1920,	1,015,800		

The quantity of sewage which may require disposal from the population of the main drainage district and tributary Metropolitan

areas, as given in the foregoing table, is likely to depend, so far as can be foreseen at present, upon (1) the quantity of water from the public water supply that will be discharged into the sewers; (2) the water entering the sewers from private water supplies; (3) the leakage of ground and storm water into the sewers; and (4) the storm water discharged into the main sewers from the sewers which are built to receive both sewage and storm water.

1. The Quantity of Water entering the Sewers from Public Water Supplies.

The quantity of water used in the municipalities comprised in the districts now under consideration has increased during past years at a much greater rate than the population. After the measures which were taken for the restriction of waste in Boston in 1883, the consumption of water per capita was considerably reduced, and in the municipalities which now compose the Metropolitan water district amounted to 65 gallons per capita in the years 1884 and 1885, and to 66 gallons in the year 1886. In 1899 the consumption had increased to 98 gallons per capita, an increase of 2½ gallons per capita per year during the thirteen years. At this rate of increase the consumption per capita in the Metropolitan district in 1940 would be about 200 gallons.

An examination of the records of the quantity of water used from the public water supply in the larger American cities shows that it is increasing rapidly in all large cities, even in cases where a large proportion of the water is supplied through meters, and at the present rate of increase the use of water will exceed 200 gallons per capita in most of the larger cities of the United States before 1940.

In the district under consideration, judging from past records and present tendencies, the indications are that the increase in consumption of water will continue indefinitely, and that it will reach 200 gallons within the next forty years. While it is possible that restrictive measures may be taken which will reduce in a considerable degree this rate of increase in the consumption of water, such as strict inspection or a more general use of meters, the tendency seems to be to use more fixtures in houses and to use fixtures which require a larger amount of water in their operation; and it is unsafe to assume

that restrictive measures will be applied, or, if so, that they will be successful in materially reducing the consumption of water. It is probable, also, that the amount of water used from the public water supply for manufacturing purposes will increase as the difficulty of getting independent water supplies of suitable quality for these purposes becomes greater.

The proportion of the public water supply which will reach the sewers cannot be determined with accuracy. Practically all of the water used within the houses will reach the sewers when the houses are connected with the sewers and other means of sewage disposal abandoned; but the water used for street sprinkling, for lawns, for extinguishing fires and much of the water which leaks from the water pipes will not reach the sewers. In the densely populated portions of the city, where there are few lawns, a greater proportion of the water supply will probably reach the sewers than in the suburban districts, and in the whole district there will be a tendency for a greater proportion of the water supply to reach the sewers each year as the population throughout the district becomes more dense.

2. *The Quantity of Water entering the Sewers from Private Water Supplies.*

The quantity of water used from private sources in the district under consideration is another item which will increase the flow in the sewers, and which cannot be determined definitely. This water comes, to a very small extent, from private supplies of water which are used for domestic purposes, but principally from factories where large quantities of water obtained from independent sources are used in the manufacturing processes and discharged into the sewers. At the present time a large quantity of water is probably used in this way in the metropolitan areas. In the report of the chief engineer of the Metropolitan Sewerage Commission in 1895, on a proposed sewer for the Neponset valley, the amount of water used for manufacturing purposes in Hyde Park, Mattapan and East Dedham was estimated to be about 20,000,000 gallons per day, of which, however, only 100,000 gallons were polluted sufficiently to require removal by the sewers at that time. Practically all of this water was obtained from private sources. With an increase in the density of population in the district it is likely that fewer private supplies will

be used, as it will become more difficult to obtain water of suitable quality.

The quantity of water from private water supplies which reaches the sewers and the quantity of water from the public water supplies which does not reach the sewers are both very uncertain, and it may be assumed that the two quantities will equal and offset each other.

3. Leakage into the Sewers.

Nearly all sewers which are laid below the level of the water in the ground receive a considerable quantity of ground water through defective joints or cracks in the sewers, and the water which enters the sewers in this way has been found to form a large proportion of their flow. Numerous observations of the leakage into the sewers of various systems in the State have been made in recent years, and the results show that it varies considerably in quantity in different seasons of the year, being greatest in the spring, when the ground water is highest.

Records of the flow in sewers recently constructed, aggregating about 137 miles in length and ranging in size from 8 inches to 36 inches show that the average leakage into these sewers before any connections were made with them amounted to 40,000 gallons per mile of sewer. Some of these measurements were made in the spring, at the time when the leakage is greatest, but others were made in the drier portion of the year. When connections are made with these sewers it is likely that the leakage will be greater, on account of the larger number of joints.

Records of flow of sewage at all times of the day and night in about 700 miles of sewers of various sizes in cities and towns of Massachusetts indicate that the leakage in a large system would probably amount frequently to nearly 70,000 gallons per day per mile of sewer, and at times when the leakage is extraordinary to as much as 80,000 gallons per mile. The extensions to the various sewerage systems which will be made in the future in Metropolitan areas may receive a somewhat less quantity of water by leakage, since a larger proportion of the sewers built in extending the systems in the future will probably be constructed with pipes of small diameter, and laid in higher lands where the amount of ground water encountered may be less; but the increase in the number of connections will probably cause an increase of leakage into the sewers

already built, and, on the whole, it seems desirable that provision should be made for a leakage of as much as 80,000 gallons per day per mile of sewer in the districts under consideration.

Estimates based on the recorded flow of sewage from the Boston main drainage and the North Metropolitan sewerage systems tend to confirm the other investigations as to the amount of leakage into the sewers, and there seems no reason to expect that the leakage per mile of sewer will differ materially, for many years in the future, from the amount which it has been found to be at the present time.

In order to learn the relation between the leakage into the sewers and the population connected with the sewers it has been necessary to estimate the probable future population per mile of sewers in the Metropolitan areas. The population per mile of sewer in different cities and towns in the Metropolitan district varies greatly; but in those communities where the land is now nearly all occupied and where portions of the area are densely populated it is found that the average population per mile of sewer is about 800. So far as can be judged at present, this ratio appears to be a reasonable one to use, and upon this assumption the leakage into the sewers would be 100 gallons per inhabitant.

The quantity of water which may find its way through man-holes at times of storm or melting snow has been found to be very considerable in the case of many sewer systems, and, in order to reduce the quantity, tight man-hole covers have been used in some places instead of the usual perforated covers. It seems probable that the leakage of considerable quantities of surface water into the separate systems of sewers can be largely prevented in the future, and it does not seem necessary to make further provision for an increase in the flow of sewage from this cause alone.

4. Quantity of Storm Water entering the Sewers.

In the districts under consideration 90.4 square miles are provided with sewerage upon the separate plan, storm water being excluded from the sewers, while the remaining 30.6 square miles are sewered upon the combined plan and the sewers receive both sewage and storm water. The Boston main drainage system, as already indicated, was designed to remove a quantity of storm water equivalent to about one-quarter of an inch of rainfall in twenty-four hours upon the area tributary to the sewers. On this basis the

quantity of storm water to be disposed of from the 30.6 square miles provided with combined sewers would amount to 133,000,000 gallons per day in the systems now tributary to the Boston main drainage works. The disposal of the storm water will be considered subsequently.

Summary.

It has been estimated that the use of water from public water supply systems is likely to amount to 200 gallons per inhabitant per day in the areas now tributary to the main drainage works within the next forty years, and that, while a considerable proportion of this water would not reach the sewers, it is assumed that the difference will be made up by the quantity of water discharged into the sewers from private water supplies. It has been estimated, also, that the leakage into the sewers will amount to about 100 gallons per inhabitant per day, and these items taken together would make the total flow of sewage equivalent to about 300 gallons per person per day. The use of water, however, varies in different seasons of the year and in different days of the week as well as in different hours of the day, and, if the average use of water should reach 200 gallons per day, the maximum use would be considerably in excess of this quantity. The maximum use of water has been found to occur either in very hot and dry weather in the summer, when much water is used for sprinkling and similar purposes, or in very cold weather in winter, when faucets are allowed to remain open to keep the water pipes from freezing. In the summer season a comparatively small proportion of the increased use of water is likely to reach the sewers, and the maximum flow of sewage resulting from the water supply is likely to occur in very cold weather in the winter season. The maximum leakage, as already indicated, is likely to be highest in the spring months, and the quantity of water used from the public water supply in the months when the leakage is highest is generally somewhat less than 90 per cent. of the average quantity of water used from public sources. In a large system like the main drainage works and its tributaries it is not essential to make material allowances for variations in daily flow, and it is evident that the maximum discharge of water into the sewers will not probably occur at the time of the maximum flow of leakage, and it seems probable that the highest flow in the sewers may be expected rather at the time of the maximum leakage than at the time of maximum flow of water, though the

two may not be greatly different. Considering the circumstances, it seems reasonable to assume that the flow of water from public and private water supplies into the sewers and the flow of leakage together will amount to about 280 gallons per inhabitant. The sewage from the districts under consideration amounts at the present time to about 180 gallons per capita per day, and, assuming that the rate of increase in the quantity of sewage per capita will be uniform, the quantity of sewage, exclusive of storm water, that would be discharged into the Boston main drainage system and tributary Metropolitan sewers up to 1940 would be about as shown in the following table: —

Year.	Estimated Population.	Quantity of Sewage per Capita (Gals. per Day).	Total Quantity of Sewage (Gals. per Day).
1900,	602,500	180.0	108,450,000
1905,	695,000	192.5	133,787,500
1910,	795,300	205.0	163,036,500
1915,	902,200	217.5	196,228,500
1920,	1,015,800	230.0	233,634,000
1925,	1,137,400	242.5	275,819,500
1930,	1,267,000	255.0	323,085,000
1935,	1,400,200	267.5	374,553,500
1940,	1,539,000	280.0	430,920,000

It will be seen from the table that the quantity of sewage that may be expected to discharge from the districts under consideration will soon be far in excess of the present capacity of the Boston main drainage works, taking into consideration that a large quantity of storm water will increase the flow of sewage, and that the time has arrived when some relief for those works is necessary unless their capacity can be materially enlarged. Moreover, when the Neponset valley main sewer was constructed provision was made for diverting the sewage from this sewer at some point in the neighborhood of the boundary line between Dorchester and Hyde Park into some other outlet, and, on account of the small size of the Neponset valley sewer below the point at which it was expected that the sewage would be diverted and of the Dorchester intercepting sewer which is its outlet, some provision will soon have to be made for relieving the Neponset valley sewer.

It has already been shown that the probable limit of the capacity of the main drainage works with moderate additions is about

154,000,000 gallons per day, this being the capacity of the tunnel when the reservoirs are full or nearly so, and when the level of the sewage in the deposit sewers at its upper end is kept at the greatest practicable height. The main sewer leading to the pumping station has a capacity of about 226,000,000 gallons per day below the last connection, and the outfall sewer from the further end of the tunnel to Moon Island a capacity of 320,000,000 gallons per day; and, if the carrying capacity of the tunnel could be increased, the quantity of sewage that the works would convey to Moon Island would be materially enlarged.

The object of the deposit sewers is to provide for the interception of sand and gravel and other heavy matters, brought down in the sewage, and to prevent them from entering the tunnel and works beyond, where they might cause trouble by forming deposits. Moreover, the current into which the sewage is discharged at the outlet is less rapid than the flow in the main sewer, and unless these matters are removed, deposits might collect near the sewer outlet. By abandoning the present deposit sewers and making provision at Moon Island for removing the matters which the present deposit sewers are designed to intercept, and by connecting the force main from the pumps directly with the tunnel, the head upon the latter could be raised and the quantity of sewage that it would carry increased. But the tunnel was not designed to withstand a materially greater pressure than will be put upon it under the present plan, and to strengthen it sufficiently and to provide works to replace the present deposit sewers, even if practicable, would require a large outlay. It would also be necessary to provide relief for the Neponset valley sewer by building a large sewer to connect with the main drainage works. The capacity of the works would again be reached before many years, and a further outlay become necessary. In view of these objections and of other considerations which will be referred to in connection with an outlet for the sewage, it does not seem desirable to attempt to provide for the relief of the Boston main drainage system and the Charles and Neponset River valleys in this way.

Proposed Method of Relief of Main Drainage Works.

The relief proposed in the original design of the main drainage works was a high-level sewer, which should remove a portion of the sewage from the higher parts of the district to the outlet by gravity.

The building of this high-level sewer was further anticipated in the construction of the main drainage works by providing a place at which this sewer might connect with the outfall works at Squantum.

An act of the Legislature of 1899, passed subsequently to the resolve directing this investigation, provides for the construction of a high-level sewer in substantial accordance with plans presented to the Legislature in a special report of the Metropolitan Sewerage Commission Feb. 11, 1899, which provides for a high-level sewer to convey sewage to a proposed outlet near Peddock's Island, but directs that no part of the proposed sewer south of the Neponset River shall be constructed until the question of an outlet has been considered by the State Board of Health. This act also provides for the creation of a South Metropolitan district, which shall embrace the present Metropolitan districts connected with the Boston main drainage system and other areas which would be served by the proposed high-level sewer. The portion of the high-level sewer north of the Neponset River, provision for the construction of which is made by that act, is now being built and several sections will soon be completed.

This sewer, as now planned, will begin a short distance north of Tremont Street in Roxbury, not far from the boundary line between Roxbury and Brookline, and, passing in a tunnel through Parker Hill, will run in a generally southerly direction to the valley of Stony Brook near Forest Hills. It will then follow in general the valley of the brook to the neighborhood of the boundary line between West Roxbury and Hyde Park, where it turns to the south-east and passes by tunnel through the divide between the Stony Brook and Neponset River water-sheds to the valley of the Neponset River, near the boundary line between Dorchester and Hyde Park.

Into this sewer at its upper end it is proposed to discharge all of the sewage flowing from the Charles River valley Metropolitan sewer by diverting this sewer from the point at which it joins the Boston main drainage sewer at Huntington Avenue and Gainsborough Street to a pumping station to be located in the neighborhood of Ward Street, and pumping it to the proposed high-level sewer. In its course through West Roxbury and Hyde Park the high-level sewer is designed to receive the sewage of districts in Roxbury, Dorchester, West Roxbury and Hyde Park that can enter this sewer by gravity. At the Neponset River the flow of the

present Neponset valley Metropolitan sewer will be intercepted near the boundary line between Hyde Park and Dorchester, and at some future time the sewage of the portion of the Neponset valley sewer below the place where the high-level sewer crosses will be pumped into that sewer.

Provision is also made for a future extension of the high-level sewer from its upper end, across Brookline and Brighton and into Newton, to relieve the Charles River valley sewer when it may become necessary to do so.

From the limit of present authorized construction of the high-level sewer at the Neponset River, the report of the Metropolitan Sewerage Commission shows that it is practicable to convey the sewage by gravity either to the present sewer outlet at Moon Island or to an outlet in the vicinity of Nut Island or Peddock's Island. By either plan the sewage of the city of Quincy would be included.

The total area which would be tributary to the proposed high-level sewer by this plan would be 109 square miles, including the area of the city of Quincy. The sewer will provide satisfactory relief for the portions of the Charles and Neponset River valleys comprised in the Metropolitan sewerage and the Boston main drainage districts, now connected with the Boston main drainage works, which require some means of relief before the main drainage works become seriously overtaxed. It is necessary to consider next what other portions of the Charles and Neponset River valleys may require relief in connection with the works now proposed.

DISPOSAL OF SEWAGE OF THE CHARLES RIVER VALLEY.

The Charles River rises near Milford and flows in a very circuitous course in a generally north-easterly direction to Boston harbor, draining a total area of 307.5 square miles. The river is a tidal stream as far up as Watertown, 10 miles above its mouth. Between Watertown and Newton Upper Falls the river falls 85 feet in about 10 miles. From Newton Upper Falls nearly to the town of Millis, a distance of 32 miles, the stream has a total fall of only 28 feet, nearly all of which is at two dams, one at Charles River Village and the other at South Natick.

The lower portion of the valley up to and including Waltham and Newton is densely populated on both sides of the stream, and all

of this territory is included in the existing Metropolitan sewerage systems.

Above Waltham and Newton and between these places and South Natick there are considerable populations at many places along the main river and its tributaries, and the population in portions of this region seems likely to grow rapidly, on account of nearness to the city of Boston. The portions of this territory on the easterly and north-easterly side of the river from Newton Upper Falls to the further limits of Dedham are included in the former Neponset valley district of the Metropolitan sewerage system, and sewers have already been provided in the West Roxbury district of the city of Boston, but none have yet been constructed in the portions of Newton and Brookline which the Neponset valley sewer was designed to serve, nor in the town of Dedham. On the westerly and north-westerly side of the river, in the valley of Stony Brook, the first principal tributary above Waltham, are located the thickly settled portions of Lincoln and nearly all of Weston. Portions of Weston, Wellesley and Needham are located within the valleys of small tributaries which enter the main river between the outlet of Stony Brook and Dedham. Between Dedham and South Natick the principal portions of the towns of Needham, Wellesley, Westwood and Dover are included within the water-shed of the river, and the natural drainage of the most thickly populated portions of these towns is towards small tributaries which enter the river in this region.

The village of South Natick, in the town of Natick, is located close to the river just above Wellesley. Above South Natick the river drains an area of 154.7 square miles, which contains the greater portions of the towns of Milford, Franklin, Holliston, Sherborn, Medway, Millis, Medfield and Norfolk, and large portions of Bellingham and Dover. The aggregate population of these towns in 1895 was about 27,000, and two of them, Milford and Franklin, near the extreme upper end of the water-shed, contain together somewhat more than half of the entire population of the drainage area above South Natick. Several of the towns are provided with public water supplies, but no general system of sewerage has been provided in any of them except Medfield, and the sewage in this case is purified upon land within the town. It is not practicable or necessary to provide a general system of sewerage for this district in connection with the present Metropolitan districts, nor is it likely that within

the next forty years there will be any need of a general system of sewerage in the valley of the Charles River above South Natick.

The populations of the towns which are located in the territory between the limits of the areas provided for by existing Metropolitan sewerage systems in the lower part of the valley and the sparsely settled territory above South Natick since 1870 have been as follows: —

Town.	Year.					
	1870.	1875.	1880.	1885.	1890.	1895.
Lincoln,	791	834	907	901	987	1,111
Weston,	1,261	1,282	1,448	1,427	1,664	1,710
Wellesley,	–	–	–	3,013*	3,600	4,229
Needham,	3,607	4,548	5,252	2,586	3,035	3,511
Westwood,	–	–	–	–	–	–†
Dover,	645	650	653	664	727	668

* Wellesley set off from Needham in 1881.

† Westwood set off from Dedham in 1897, with a population of 1,023.

The character of the various towns is for the most part very similar. There are no systems of sewers in any of the towns, and two of them, Dover and Westwood, have no system of public water supply. Lincoln, Weston, Westwood and Dover are largely residential communities, containing very few manufacturing establishments. The land is generally held in large estates, and the villages are small and not closely built. The future growth of these towns seems likely for the most part to be slow and the population widely distributed. Needham and Wellesley contain more closely built up areas than the other towns, and there are a few manufacturing establishments, principally in Needham. These towns seem likely to have a steady growth in population in the future, on account of their attractiveness as places of residence, and sewers are likely soon to be required. It is not likely that under natural conditions sewers would be required for many years in the other towns, excepting possibly in small areas near the Charles River in Weston; but the thickly settled portions of Weston and Lincoln are situated in the valley of Stony Brook, which is used as a source of water supply by the city of Cambridge, and it is possible that systems of sewerage may be required for small portions of these towns before

many years, in order to protect the purity of the Cambridge water supply.

The village of South Natick, as already indicated, is situated close to the river, near the boundary of the town of Wellesley. It is a manufacturing village supplied with water from the Natick water works, but it is situated at so low a level that its sewage could not be disposed of in connection with the Natick system without pumping it to a considerable elevation, and it has been omitted from the Natick system. The village is quite densely built up, and, while it does not appear to be growing rapidly at the present time, a system of sewers may soon be found desirable.

An estimate of the probable future population of the towns within the territory described is given in the following table: —

Town.	Year.				
	1900.	1910.	1920.	1930.	1940.
Lincoln,	1,150	1,400	1,830	2,620	3,840
Weston,	1,880	2,300	3,030	4,280	6,050
Wellesley,	4,890	6,500	8,890	12,280	17,010
Needham,	4,250	6,030	8,660	11,910	16,010
Westwood,	1,140	1,400	1,840	2,600	3,680
Dover,	680	715	840	1,120	1,610
South Natick (village),	1,300	1,600	1,900	2,200	2,500

An examination of all of these towns, and of contiguous territory included in the valley of Charles River between the areas at present provided for by Metropolitan systems and the rural areas above South Natick, has been made, to determine whether provision should be made for the sewerage of these towns in connection with the Metropolitan system, or whether the sewage should be disposed of in some other way. Estimates of the probable cost of disposing of the sewage by various available plans have been made, based upon the cost of similar works in other places, but these estimates do not include the cost of local sewers, which would be common to any plan that might be considered.

By examining a map of the Charles River valley it will be seen that on the westerly side of the river the first principal tributary above Waltham and the territory included in existing Metropolitan sewerage systems is Stony Brook, which drains the thickly settled portions of Weston and Lincoln, together with small and very

sparsely inhabited portions of Lexington and Waltham, and possibly a few acres in Wayland. From the river to the outer limits of this valley the distance is about 7 miles. Passing up the valley of the river on the westerly side from the edge of the water-shed of Stony Brook to Dedham, through the towns of Weston, Wellesley and Needham, it is found that the tributaries of the river from the west and south-west within this distance are nearly all small streams, whose water-sheds extend back in most cases, only from one to two miles from the river to a range of hills, while beyond these hills the land drains toward the west and south-west in streams which join the river many miles above Waltham. The thickly settled portions of Wellesley and Needham are nearly all within the valleys of the latter streams; but the territory in these towns which drains toward the river between Waltham and Dedham contains a considerable population.

In studying the future sewerage of the portions of the Charles River valley not provided for in existing systems, the valley of Stony Brook and the water-sheds along the westerly side of the river between Stony Brook and Dedham appear to be the first to require consideration. Any prediction that can be made of the probable future population of these areas, or as to their probable requirements in the matter of sewerage, may be greatly at variance with the actual conditions. In many portions of these areas the estates are large and it seems likely to be a long time before the population will become so dense as to require sewerage, and considerable areas in Needham are controlled by the city of Newton and the town of Brookline to protect their water supplies. Other portions of these areas are quite close to regions which are already thickly populated and are crossed by railroads, and with the continued growth of the Metropolitan district these areas seem likely to become much more thickly inhabited than at present. The probable need of sewerage in the valley of Stony Brook and in the small drainage areas on the westerly side of the river between Stony Brook and Dedham has been considered, and the various ways in which sewerage can be provided when necessary have been examined.

Lincoln.

The present population of this town is estimated to be 1,150. The population is widely scattered throughout the town, the principal collection of houses at the present time being in the village of Lincoln near the centre of the town, about 1½ miles from the Fitchburg Railroad, where there is a very small village which does not seem destined to grow to any considerable size. It is possible that a village may grow up near the railroad, but from present indications it will be many years before any portion of this town will require sewers, unless it shall be found desirable at some future time to construct sewers to protect the purity of the Cambridge water supply.

Approximately two-thirds of the area of the town is included within the Charles River water-shed, the remaining portion draining toward the Sudbury River. The main village is within the water-shed of Stony Brook, while a considerable section in the north-westerly corner of the town is within the valley of Hobbs Brook, and a very small area in the southerly part of the town is in the valley of Cherry Brook, both of which are tributaries of Stony Brook. It would be feasible to collect the sewage of the central portion of the town, including the present village, and convey it by gravity to a filtration area near the south-westerly boundary of the town and outside of the Charles River watershed; but if a considerable population should grow up in the vicinity of the railroad, especially about the South Lincoln station, the sewage could not probably be delivered into this system without pumping. If a village should grow up in the future at South Lincoln, and it should be found desirable to provide sewerage for the main portion of the valley of Stony Brook within the town, the sewage could probably be best collected at a pumping station in the valley of the brook near the boundary between Lincoln and Weston, and pumped to the filtration area already suggested.

There is no doubt that the sewage of all the portions of Lincoln in the Charles River valley that are at all likely to become densely populated can be satisfactorily purified by the plan above outlined; but the possibility of disposing of the sewage in connection with the town of Weston and the Metropolitan sewerage system will be considered with Weston.

Weston.

The present population of this town is estimated to be 1,880. The population is located mainly in the village of Weston, near the middle of the town, and in one or two very small villages in the north-westerly part of the town along the Fitchburg Railroad. The northerly part of the town is drained by Stony Brook and by Cherry Brook, a tributary of Stony Brook, and, excepting the very small villages referred to, this territory is very sparsely populated at the present time. The Fitchburg Railroad follows the main stream of Stony Brook quite closely, and the population in this region is quite close to the brook.

The central village of Weston is in the valley of a tributary of Stony Brook, which enters that stream near the head of the Stony Brook reservoir of the Cambridge water works. The south-easterly corner of the town is nearly all included in the valley of a small brook which flows into the Charles River nearly opposite Riverside. This district, while at the present time very sparsely populated, is building up somewhat rapidly; but the estates are large, and it is not likely that sewerage will be required for many years. The south-westerly portion of the town is in the valley of Waban Brook, and is nearly unpopulated and so situated that it is not likely to contain any considerable population.

The present thickly settled portions of the town would probably not require sewerage for a long time in the future, were it not that the necessity for protecting the purity of the Cambridge water supply may make it necessary to provide some means of sewage disposal for small areas. The portions of the town for which such a system seems likely to be required are the districts in the valley of Stony Brook and Hobbs Brook, which joins Stony Brook in the northerly part of the town, and the district in which the main village of Weston is located. Sewage from these places might be collected near the Charles River, between Stony Brook and the village of Riverside.

An examination of the territory in Weston shows that the land all along the Charles River, between Stony Brook and Riverside, is of excellent quality for the purification of sewage by filtration; but this territory may become thickly populated, and the location of a sewage-disposal system in this region might be sufficiently objec-

tionable to warrant going to a greater distance and incurring a greater expense in disposing of the sewage. An examination of the territory available indicates that by pumping the sewage a distance of about three miles it can be discharged upon an area of land remote from any habitation at the present time, and well suited to the purification of sewage by filtration.

Estimates have been made of the probable cost of collecting and pumping the sewage of Weston to the filtration area referred to, and estimates have also been made of the cost of works for disposing of the sewage of both Weston and Lincoln by this plan. The feasibility of disposing of the sewage of both Weston and Lincoln in connection with the South Metropolitan district has also been considered, and an estimate of the cost to the towns and to the district has been prepared. It is evident from the investigations that if these towns should join the Metropolitan district it might be possible for them to dispose of their sewage at less cost than by purification on lands within their own limits; but the cost of construction of works to receive the sewage, if paid for by the Metropolitan district would entail a great expense upon the district in excess of the assessments that would be received from the towns on the basis upon which assessments have been made in the past. If these towns, or either of them, should join the Metropolitan system, they should join at the present time, so that provision can be made for receiving and disposing of the sewage whenever it would become necessary to do so. If they should begin paying assessments at present, the payments that might be made before sewers are required might so greatly increase the cost of joining the Metropolitan system that the cost would amount to nearly as much as the cost of purifying the sewage upon land at some future time, when a system of sewage disposal becomes necessary. Considering that there are suitable disposal areas within the limits of each town upon which it is practicable for the towns to dispose of their sewage whenever it may become necessary at a not unreasonable cost, and considering the probability that a general system of sewerage for either town will not be found necessary for a long time in the future, it does not seem desirable to provide for the sewerage of Weston and Lincoln in connection with the Metropolitan district; and the results of the investigations indicate that the best method of disposing of the sewage of both Weston and Lincoln for many years in the future will be to purify it by filtration.

For the protection of the water supply of Cambridge, however, a sewerage system for portions of Weston may be required before long, and it may become desirable to dispose of the sewage temporarily by discharging it into the Metropolitan system. This can be done by discharging the sewage into the sewers of Newton or Waltham, and it is probable that sewage from the portions of Weston and Lincoln which may require sewerage to protect the Cambridge water supply can be disposed of in this way until a general system of sewerage for the towns becomes necessary.

Disposal of the Sewage of Small Areas in Weston, Wellesley and Needham which drain directly into the Charles River between Stony Brook and Dedham.

An examination of the map shows that there are several small areas along the south-westerly side of Charles River in the towns of Weston, Wellesley and Needham draining directly into the river, on the opposite side from Newton, which are not included in existing Metropolitan sewerage districts.

All of these small areas drain naturally toward the main sewer of the city of Newton, which is in process of construction by that city, and which is designed to receive the sewage of that portion of Newton in the valley of the Charles River beginning at a point in the neighborhood of Newton Upper Falls and extending along the valley through Newton Lower Falls, Riverside, Auburndale and West Newton to the Charles River valley sewer of the Metropolitan sewerage system, which it joins at a point in Newton near Cheesecake Brook. The higher portions of the city of Newton are to be served ultimately by the proposed high-level gravity sewer when it is extended to that city; but at the present time the sewer in the valley of the Charles River, already described, receives much of the sewage, which will eventually be discharged into the high-level sewer.

The sewage of the small districts on the opposite side of Charles River in the towns of Weston, Wellesley and Needham, which have been described above, can be brought into the Newton sewer, and thus into the Metropolitan sewerage system, by the construction of short connections, including river crossings.

The first tributary of Charles River south of Stony Brook enters the river just below Riverside. This stream drains an area of 1.8

square miles, which is at present very sparsely populated. In the lower portion of the water-shed the land is suitable for filtration purposes; but this land is already valuable, and it is probable that, by the time the water-shed of the brook is inhabited sufficiently to require sewerage, the disposal of sewage upon land in this valley will be out of the question. It will be practicable to collect the sewage of this valley and the small water-shed south of it and contiguous territory bordering the river in Weston, aggregating 2.7 square miles, as shown on the accompanying plan, and to dispose of it in connection with the sewage of the town of Weston. Since the territory is within Weston, it would probably be best that its sewage be disposed of in connection with that of the remainder of the town; but the water-shed is so situated that it will be practicable to dispose of the sewage into the main sewer of the city of Newton, already mentioned, on the opposite side of the river.

The next area is situated chiefly in Wellesley, opposite Newton Lower Falls, and includes a small area draining directly into the Charles River, the total drainage area being 1.58 square miles. A portion of this district near Charles River contains already considerable population and the entire water-shed is being built up rapidly so that it is probable that sewerage facilities will be required in a short time for at least a portion of the district. While suitable land for the purification of the sewage is found along the river bank, the location of filtration works, even of small size, in this region, might be objectionable.

The other ways of disposing of the sewage are to pump it into the general system of the town of Wellesley, or to discharge it by gravity into the Newton sewer on the other side of the river, — a method of disposal which appears to be the most feasible, and which does not seem likely to require a great expense for sewers.

Rosemary Brook valley has an area of 3.75 square miles. At its lower end and within the town of Wellesley this area is very sparsely populated, and contains the wells and other works for collecting ground water for the supply of the town of Wellesley. The upper end of the water-shed within the town of Needham is more densely populated, and contains a portion of the village of Highlandville. It would be practicable to purify the sewage of Highlandville within this water-shed probably for a good many years in the future; but, on account of the location of the Wellesley

water supply, it will probably be found desirable to remove the sewage from the water-shed. It would require a long sewer to convey the sewage of Highlandville through the Rosemary Brook valley to the Newton sewer, and such a sewer would be of no special value to the remainder of the water-shed, which is, as already stated, very sparsely populated.

A considerable portion of Highlandville appears to be at such an elevation that a sewer can be laid so as to receive the greater portion of the sewage of the village, and dispose of it by gravity in connection with the sewerage system of the village of Needham. The remaining portions of the village, which are at a lower level and from which the sewage cannot be discharged into the Needham sewers by gravity, will have to be dealt with in some other way. At some future time, when the valley becomes populated, it will doubtless be best to dispose of the sewage of the low portions of Highlandville in connection with the sewage of the remainder of the valley, and probably discharge it into the Newton sewers. In the mean time, should sewers become necessary, the best method of disposing of the sewage of Highlandville will probably be to collect it at some convenient point and to pump it into the main sewers of the village of Needham.

Further up the river, above the mouth of Rosemary Brook, there is an area opposite Newton Lower Falls amounting to 1.45 square miles, below the land of the Newton water works, located chiefly in the valleys of two brooks, which flow into the river opposite Newton Upper Falls village. It does not appear to be practicable to purify the sewage of this section within its own area; part of the area is in Needham and part in Wellesley, and to dispose of the sewage in connection with a system for either town would require pumping. It will be practicable to discharge the sewage into the Newton sewer close to the river, when this sewer is completed, and this would probably be the least expensive method of disposing of the sewage of this area.

Still farther south-west there is a territory on the north-westerly slope of Bird's Hill not included in the territory purchased to protect the Newton water supply, a large part of which could be provided for in connection with the district in Needham opposite Newton Lower Falls, while the sewerage of the remainder would probably best be provided for by a sewer running in a southerly direction to the Neponset valley sewer.

Studies have been made as to the probable length of time during which the Newton sewer and the Charles River valley Metropolitan sewer would serve these districts, in addition to the districts which they were designed to serve. The results show that these sewers will probably be capable of serving these districts in Weston, Wellesley and Needham, in addition to those for which they were designed, for many years in the future, if the quantity of sewage per inhabitant is not excessive; and, when the high-level sewer is extended to Newton, ample provision for the relief of the Newton and Metropolitan sewers can be made.

South Natick.

The population of this village at the present time is estimated to be 1,300. Though provided with a public water supply it has no system of sewerage and was not included in the general plan of sewerage for the main portion of the town of Natick. In order to dispose of the sewage into the Natick system it would be necessary to pump it to a considerable elevation to reach the Natick sewers, and it would have to be pumped a second time before reaching the filtration area. The disposal of the sewage of this village in this way would decrease materially the capacity of the Natick sewers for disposing of the sewage of the main portion of the town, and under the circumstances it is desirable to dispose of the sewage of the village of South Natick by some other plan. It is probably not practicable to collect the sewage and dispose of it on any separate filtration area without pumping, because a large part of the village is situated on land which is elevated only a few feet above the river. To collect and pump the sewage of this village alone to a suitable filtration area would be expensive, and the investigations indicate that it would probably be best to dispose of the sewage in connection with the sewage of the main portion of Wellesley.

Wellesley.

The estimated population of this town at the present time is 4,890. The sewerage of small areas draining easterly toward the Charles River in the neighborhood of Newton has already been considered. Nearly all of the thickly settled portion of Wellesley is in the valley of Fuller's Brook, a tributary of the Charles River, which enters that stream about three-quarters of a mile below South

Natick. The brook drains a large section of Needham, which does not contain any considerable population. The main village of Wellesley will soon need sewerage, though it may be several years before a system will be constructed. Just above the point where the river is joined by Fuller's Brook is the outlet of Morse's or Waban Brook, which drains a large area in Weston, Wellesley and Natick. This territory is very sparsely populated at the present time. The sewage of the thickly settled portions of Wellesley would naturally be collected in a main sewer in the valley of Fuller's Brook, and the only place in the town where it appears to be practicable to dispose of this sewage by gravity is upon land near the mouth of Fuller's Brook, near Charles River.

While this land is quite near the limits of the thickly settled portion of Wellesley, it is nevertheless probable that the sewage of the town and of South Natick also could be disposed of satisfactorily at this place for many years in the future, by the use of rapid systems of filtration if necessary, without being objectionable to the inhabitants of the region, and at a less expense than in any other way; but the circumstances may be such, when the town prepares to construct a sewerage system, that it will be deemed desirable to remove the sewage to some point further from the town, if practicable, and four other areas which might possibly be used for the purification of the sewage of Wellesley and South Natick have been considered. One of these areas is located in Dover, another in Natick, a third in Needham and the fourth in Wellesley; and, in order to deliver the sewage upon any of these areas, pumping will be necessary. Of these areas, the one in Needham is nearest the point where the sewage of Wellesley and South Natick can best be collected. The land is of excellent character for the disposal of sewage by intermittent filtration, and the cost of purifying the sewage of Wellesley and South Natick upon this area would be less than upon any of the other areas, excepting the one near the mouth of Fuller's Brook.

The area in Wellesley which is available for the disposal of the sewage by pumping is in a nearly uninhabited portion of the town, and the land is excellent for sewage purification. To dispose of the sewage upon filtration areas in Dover or Natick would be much more expensive than by the other plans mentioned.

The feasibility of disposing of the sewage of Wellesley and South Natick into the Metropolitan sewerage system has also been consid-

ered. The sewage would have to be pumped by any plan that would provide for all of the thickly settled portion of Wellesley; and the best way of connecting Wellesley with the Metropolitan system would probably be to pump the Wellesley sewage over into the large intercepting sewer of the city of Newton at Newton Lower Falls, through which the sewage would flow to the Charles River valley Metropolitan sewer.

Estimates have been made of the comparative cost to the town of Wellesley of works for the disposal of sewage: (1) by pumping it to a filtration area in Needham; (2) by pumping it to a filtration area in Wellesley; (3) by pumping it into the Metropolitan sewerage system. These estimates include the cost of pumping stations, pumps and other appurtenances, reservoirs, force mains and filter beds, together with the maintenance of those works; but the estimates do not include the cost of sewers in the town which would be common to all of the plans of sewerage which have been considered. It is assumed for the present that if Wellesley should join the Metropolitan district the Newton sewer would be taken by the Metropolitan district, and that Wellesley would be admitted to the district on the same basis as the other towns; that is, from the time of admission Wellesley would pay toward the interest and sinking fund requirements of the Metropolitan district, in the proportion that its valuation bears to the valuation of the remainder of the district, and that it would pay toward the maintenance of the Metropolitan works in the proportion that its population bears to the population of the whole district. On this basis the comparative cost of works by the three plans and of annual interest, sinking fund and maintenance requirements would be as follows: —

1. Cost of pumping and disposing of the Sewage of Wellesley and South Natick upon a Filtration Area in the Town of Needham.

Estimated total cost of pumping station, pumps, force main, filter beds, etc.,		$95,300
Estimated yearly interest and sinking fund for forty years on above total cost of works,	$4,815	
Average annual cost during forty years for maintenance of pumping station,	3,200	
Average annual cost during forty years for maintenance of filtration area,	1,875	
Total annual cost,		$9,890

The cost of disposing of the sewage of Wellesley under this plan would be somewhat reduced if Wellesley and Needham should join, and dispose of the sewage of both towns at the same place.

2. Cost of pumping and disposing of the Sewage of Wellesley and South Natick upon a Filtration Area in Wellesley.

Estimated total cost of works, on basis comparable with previous estimate,		$116,300
Estimated annual interest and sinking fund for forty years on above total cost of works,	$5,875	
Average annual cost during forty years for maintenance of pumping station,	3,500	
Average annual cost during forty years for maintenance of filtration area,	1,875	
Total annual cost,		$11,250

3. Cost of pumping and disposing of the Sewage of Wellesley and South Natick into the South Metropolitan Sewerage System.

Estimated total cost of works, on basis comparable with previous estimate,		$91,300
Estimated annual interest and sinking fund for forty years on above total cost of works,	$4,610	
Average annual cost of pumping and maintenance,	3,450	
Total annual cost of works,		$8,060
Estimated annual proportion of interest and sinking fund charges of Metropolitan district,		5,630
Estimated annual proportion of maintenance charges of Metropolitan district,		510
Total annual cost of disposing of sewage into the Metropolitan system,		$14,200

It will be seen, from an examination of the above table, that the cost to Wellesley of disposing of the sewage from the main portion of the town into the Metropolitan system would be about $2,950 greater per year than the cost of disposing of its sewage upon land within its own limits. The saving to Wellesley would be still greater if the area near Fuller's Brook should be used for the disposal of its sewage.

Moreover, the capacity of the Newton sewer, into which the Wellesley sewage would naturally be discharged would not be sufficient to receive and remove the sewage of Wellesley in addition to the quantity which it now receives; and, even after the high-level sewer is built and the Newton sewer relieved of a considerable

portion of the area now tributary to it, the capacity of the Newton sewer will still probably be insufficient, after a few years, for the removal of the sewage of Wellesley in addition to the quantity naturally tributary to it. There will, therefore, probably be a material additional cost to the Metropolitan district to make provision for receiving and disposing of the Wellesley sewage.

In the foregoing estimates no account has been made of the small areas in the easterly portion of Wellesley which have already been considered, and from which sewage may at some time be discharged into the Metropolitan system.

Judging from the foregoing estimates, it is evidently not for the interest of either Wellesley or the Metropolitan district to dispose of the sewage of Wellesley into the Metropolitan system. There is ample opportunity in the vicinity of Wellesley for the town to purify its sewage for a great many years in the future; and the investigations indicate quite definitely that this method of disposing of the sewage will be the best that it is practicable for the town of Wellesley to adopt.

Needham.

The estimated population of Needham at the present time is 4,250. The population is principally in the main village of Needham and in the village of Highlandville. There is also a considerable population in the extreme northerly part of the town, opposite Newton Upper Falls. Approximately half the area of the town drains naturally toward the Charles River below Dedham, while the drainage from the remainder enters the river above Dedham. Along the north-easterly side of the town there is a high ridge parallel with Charles River and about a mile distant from it, and the territory on the north-easterly side of the ridge all drains directly toward the river below Dedham. A considerable portion of this area is controlled for purposes of water supply by the city of Newton and the town of Brookline, and a large portion of the remainder is so situated that it is not likely to become densely populated for a great many years. The north-westerly end of this territory, however, opposite Newton Upper Falls, is likely to become quite densely populated. The future sewerage of this valley and of the village of Highlandville, located within the water-shed of Rosemary Brook, a tributary of the Charles River which enters that stream between Newton Upper Falls and Newton Lower Falls, has already been

considered. A considerable territory in the westerly part of the town is tributary to Fuller's Brook, which flows toward Wellesley. This area is very sparsely inhabited, and does not seem likely to become densely populated for a long time. The main village of Needham is situated upon a high, sandy and gravelly plain near the centre of the town, nearly all of it being in the valley of Colburn's Brook and its tributaries. This village is quite densely populated, and is likely to require sewerage before many years, but on account of the character of the soil the need of sewers does not appear to be urgent at the present time. There appear to be three ways by which it will be practicable to dispose of the sewage of Needham Village when a system of sewerage becomes necessary. One is to pump the sewage in a westerly direction, upon land already mentioned in considering the disposal of the sewage of Wellesley. This area is excellently adapted for the purification of sewage, and is so located that it would seem to be a very satisfactory filtration area.

Another plan by which the sewage of Needham can be disposed of is to discharge it upon filter beds along the Charles River, south or south-east of the main village of Needham. The Needham water supply is taken from the valley of Bird's Hill Brook in this region, and it may before long be necessary to take an additional supply of water from the lands near the river. The population in the neighborhood is increasing and land is undoubtedly quite valuable. Moreover, the river and its banks are used as a pleasure resort by large numbers of people at the present time, and this use is increasing rapidly. Considering all the circumstances, it is not desirable to construct works for the purification of sewage at any place along the Charles River in this region.

The estimated annual cost of interest, sinking fund and maintenance of works for pumping the sewage and purifying it upon land within the limits of Needham, which has already been referred to, is $9,120. This estimate does not include the cost of a system of sewers in the town which would be common to all of the plans that have been considered. It is probable that, if Needham and Wellesley should unite and dispose of their sewage upon the same filtration area, a considerable saving in the expense of maintaining the area could be effected.

The feasibility of disposing of the Needham sewage into the Metropolitan sewerage system has been carefully examined. The

sewage of Needham would naturally be collected near the Charles River, at about the point where it is crossed by Dedham Avenue. From this point a sewer would be laid down the valley of the river, probably crossing to the right bank near Dedham Avenue. It would subsequently be necessary to cross again to the left bank before reaching Causeway Street; thence the sewer would follow Causeway Street, passing under Boundary ditch, which forms the boundary of the town of Needham. From this point a sewer could be laid to the Metropolitan sewer by two routes: one across the lands of the Brookline water supply and across the river at Cow Bay to the Metropolitan sewer on the easterly bank of the river; the other down the left bank of the river nearly to Dedham, and there across to the right bank and to Mother Brook and the Metropolitan sewer in the valley of that stream. The latter plan would be the more difficult and expensive, but it would avoid laying a sewer across lands from which the town of Brookline derives its water supply, and would provide for sections of Dedham which may require sewerage at some future time, and the estimates of cost of connecting with the Metropolitan system are based upon that plan.

If the usual custom were followed, the Metropolitan sewerage district would lay a sewer up the valley of the Charles River to the boundary line of the town of Needham, and it is estimated that such a sewer would cost $66,000.

The annual cost to the town of Needham of disposing of its sewage in connection with the Metropolitan system, on a basis comparable with the estimated annual cost of disposing of the sewage by filtration already given, is $3,340. If Needham should be admitted to the South Metropolitan district, the additional annual cost to the district, over the amount that would be received by assessments from Needham, would probably be in the neighborhood of $1,000.

Comparing the foregoing estimates of the annual cost of disposing of the sewage of Needham by the two plans, one providing for the purification of the sewage within the limits of the town and the other for discharging it into the Metropolitan system, it is seen that if Needham should enter the Metropolitan system at the present time it could probably dispose of its sewage more cheaply than by purifying it on land within the town, but it would be a disadvantage to the district if the usual custom of building a sewer to the Need-

ham boundary line should be followed. If Needham should pay a sufficient assessment to the Metropolitan district to fully cover the cost to the district of building a sewer to admit the town, the cost to Needham would still be considerably less than the cost of purification, even in conjunction with Wellesley.

But, as has already been stated, the soil upon which the thickly settled portion of Needham is built is largely sand and gravel, and the same appears to be true of Highlandville, so that sewers are not likely to be found necessary in either village for several years. If Needham should enter the Metropolitan district at the present time, it is possible that the aggregate of assessments that would be paid before sewers would be found necessary would so increase the cost that the saving by joining the Metropolitan system would be greatly reduced. Considering all the circumstances, it does not seem desirable that Needham should be made a part of the South Metropolitan sewerage district.

Westwood.

The estimated population of this town at the time it was set off from Dedham, in 1897, was 1,023. A portion of the town lies in the valley of the Neponset River, and will be considered in connection with the sewerage of that region. The principal portion of the town, including the main village, is in the valley of a tributary of the Charles River which enters that stream about half a mile above the place where it is crossed by Dedham Avenue, the principal road between Dedham and Needham. The village is situated near the top of a high ridge, more than 100 feet above the level of the river. The town is not provided with a system of public water supply, and sewers do not seem likely to be needed for many years. The sewage can be satisfactorily disposed of, when a system becomes necessary, upon land in the valley of the brook which receives at present the drainage from the region about the main village. This method of disposing of the sewage would probably be the cheapest for the town to adopt, judging from such estimates as have been made; but an estimate of the probable cost of connecting the town with the Metropolitan district and discharging its sewage in connection with the sewage of Needham into the Metropolitan system has also been made; and the results indicate that if sewers were to be built at the present time it might possibly be a little less expensive for the

town to connect with the Metropolitan system, but considering that sewers are not likely to be needed for many years, it does not seem desirable to make any provision for this town in connection with the Metropolitan works.

Dover.

The valley of the Charles River above the tributaries which enter from the villages of Weston and Needham is very sparsely settled up to the neighborhood of Wellesley, a distance of many miles. Along this reach of the river there is only one very small village. A large part of Dover is within the water-shed of the river in this region, but the population of this town is exceedingly small, and it is not yet provided with a public water supply. It seems unnecessary to provide for the sewerage of this town in any way at the present time.

DISPOSAL OF SEWAGE FOR THE UPPER PORTION OF THE NEPONSET RIVER VALLEY.

The main stream of the Neponset River rises in Foxborough and flows in a generally north-easterly direction to Dorchester Bay, draining an area of 114 square miles. Along the middle portions of its course there are very extensive areas of low wet lands known as the Fowl Meadows, which border the river for several miles. Above these meadows the stream has a rapid fall, and many factories and mills are located on the stream and its tributaries. In this portion of its course the river is highly polluted, chiefly by waste liquors from manufacturing establishments which are discharged into the stream or its tributaries. Below the Fowl Meadows and down to the mouth of the river there is a considerable fall, nearly all of which is utilized for power by means of several dams, forming a series of mill ponds. The river has two principal tributaries: one is the east branch, which rises in Stoughton and Sharon, and, flowing through Canton, joins the main river near the upper end of the Fowl Meadows; the other is Mother Brook, which flows from the Charles River into the Neponset River at Hyde Park.

The lower portion of the valley is quite densely populated, and is included in the Neponset valley section of the Metropolitan sewerage system. The main sewer for this district is intended to provide for the removal of the sewage of those portions of the city of Newton and the town of Brookline which are not provided for by

the Metropolitan system for the Charles River valley, together with the sewage of the towns of Dedham, Hyde Park and Milton and portions of the Dorchester and West Roxbury districts of the city of Boston, but this sewer was not designed to receive sewage from the portion of the Neponset valley above Hyde Park. The sewer as at present constructed begins in the West Roxbury district of Boston on the easterly side of Charles River, not far from the limits of Newton, and extends along Charles River to Mother Brook, and thence down the valley of Mother Brook and along the northerly side of the Neponset River to an outlet into the Dorchester intercepting sewer of the city of Boston.

At the time the Neponset valley sewer was constructed it was assumed that a high-level sewer would eventually be built across the Neponset valley in the vicinity of the boundary line between Hyde Park and the Dorchester district of Boston, which would receive the sewage from the Neponset valley sewer; and the latter sewer was designed to be of sufficient size to provide for the collection and removal of all of the sewage of the district down as far as the point where the high-level sewer was expected to cross until the year 1930. Below this point the size of the Neponset valley sewer is only sufficient for a very limited number of years in the future; and it is consequently necessary to provide some relief for this sewer, in order to avoid the necessity of discharging the sewage into the river or local water courses in this region. When the sewage of the Neponset valley sewer above this place is diverted, the portion below where the high-level sewer is expected to cross will be of ample size for the district which this portion of the Neponset valley sewer is designed to serve for many years.

The middle portions of the Neponset valley above Hyde Park, in which the Fowl Meadows are located, are very sparsely populated. The lands on both sides of the meadows are high and are drained by several small tributaries of the Neponset River, but there are no considerable villages in this portion of the valley. A portion of the town of Westwood and a small portion of Norwood not yet containing a considerable population are situated in the valley of Purgatory Brook, a tributary of the Neponset River from the north, which enters the main stream near the middle of the Fowl Meadows, and these areas may require sewerage at some future time. On the easterly side of the valley there is a small population in the valley of

Ponkapoag Brook, which enters the Neponset River from the east a little below Purgatory Brook, and it is possible that sewers may at some time be required in this valley, but this necessity is not likely to become apparent for many years.

Above the Fowl Meadows in the valley of the main stream are located the growing towns of Norwood and Walpole, and in the valley of the East Branch the towns of Canton, Stoughton and Sharon. Practically all of the thickly settled portions of these towns are within the valley of the Neponset River. The water-shed of the river also embraces very small portions of Dover, Medfield, Foxborough and Randolph, but these are rural regions which do not now seem likely to become so densely populated as to require sewerage.

An examination of the portions of the Neponset River valley above Hyde Park which are not provided for in the present sewerage system, or by the proposed high-level sewer, has been made to determine what further relief may be required for the sewerage of this valley.

On the main stream, as already indicated, the most important towns are Norwood and Walpole. Both of these towns are provided with public water supplies and both are growing quite rapidly, but no sewers have yet been provided in either town. On the East Branch are the towns of Canton, Stoughton and Sharon, all of which have been provided with public water supplies for several years, but none of them has as yet a system of sewerage.

The population of these towns since 1870 has been as follows : —

Year.	Walpole.	Norwood.	Sharon.	Stoughton.	Canton.
1870,	2,137	–*	1,508	4,914	3,879
1875,	2,290	1,749	1,330	4,842	4,192
1880,	2,494	2,345	1,492	4,875	4,516
1885,	2,443	2,921	1,328	5,173	4,380
1890,	2,604	3,733	1,634	4,852†	4,538
1895,	2,994	4,574	1,717	5,272	4,636

* Norwood set off from Dedham and Walpole in 1872.
† Avon set off from Stoughton in 1888.

All of the towns would be classed as manufacturing communities, with the exception of Sharon, which is principally a residential town and a summer resort. Norwood and Canton are becoming to a con-

siderable extent places of residence for people who do business in Boston, and seem likely to have a steady growth from this cause. At the present time Norwood is growing the most rapidly of all of the towns, and this town is likely to require a system of sewerage within a very few years. The town of Canton seems likely to require a system of sewerage before very long, as may also the town of Stoughton. It will probably be many years before sewerage is required in Walpole or Sharon.

An estimate of the probable future population of these towns up to 1940 is as follows: —

Year.	Walpole.	Norwood.	Sharon.	Stoughton.	Canton.
1900, ...	3,440	5,540	1,940	5,200	5,130
1910, ...	4,590	8,000	2,440	5,660	6,610
1920, ...	6,380	11,450	3,120	6,960	9,110
1930, ...	8,930	16,250	4,160	9,280	12,980
1940, ...	12,370	22,590	5,830	12,340	18,110

The question as to whether these towns should be made a part of the Metropolitan district, or whether they should be required to dispose of their sewage in some other way, has been considered, and investigations have been made as to the means by which each may dispose of its sewage independently, and the means by which they may all be brought into the Metropolitan system. Estimates of the probable cost of works for the disposal of the sewage of each town, both by discharge into the Metropolitan sewerage system and by the various possible ways in which the sewage can be otherwise disposed of, have been prepared upon the basis of the cost of similar work in other places; but these estimates do not include the cost of local sewers or of any other work that is common to all of the plans considered for the disposal of the sewage of any particular town. The results are presented in such a form as to show the estimated yearly cost to each town of the various plans considered, for a period of forty years, including interest, sinking fund and maintenance.

Feasibility and Cost of disposing separately of the Sewage of Each Town in the Neponset Valley.

Walpole.

The present population of this town is estimated to be 3,440. The population is principally located in Walpole Centre and East Walpole, both of which communities are manufacturing villages situated on the Neponset River. In neither village is the population dense and sewers are not likely to be required for several years. The topography of the town and location of the villages are such that it is not practicable to collect and dispose of all of the sewage by gravity within the limits of the town. The village of East Walpole is located close to the Norwood boundary line, and the population in this village is growing and extending into Norwood.

An examination shows that the filtration area which appears to be most favorably situated for the use of the town of Norwood is adapted to receiving the sewage both of Walpole and the main portion of Norwood by gravity, and it will probably be best for both towns to dispose of their sewage at the same place. An estimate of the probable annual cost to Walpole of interest, sinking fund and maintenance charges for the next forty years, based upon the cost of works for receiving and conveying the sewage to the filtration area referred to, is $2,753 per year; but this estimate does not include the cost of sewers in the town which would be common to either of the plans that have been considered for the disposal of the sewage.

Norwood.

The present population is estimated to be 5,540, and the town appears to be growing very rapidly. It is a manufacturing town, but is also becoming a place of suburban residence, and it seems likely to require sewerage within a very few years. The contour of the town is such that the sewage from nearly all of the thickly settled portion, together with all the sewage of Walpole and of the portion of Norwood bordering Walpole, can be collected conveniently by gravity at some point near the Neponset River. A small portion of Westwood, in the valley of Hawes Brook, now sparsely inhabited, can be provided with sewerage in connection with the Norwood works if necessary in the future.

An area of land well adapted to the purification of sewage by filtration, and well located for the purpose, has been found, which is capable of receiving and purifying all of the sewage of Norwood and Walpole for a very long time in the future. Estimates of the probable cost of the disposal of the sewage of Norwood and of Walpole upon lands available for the purpose have been prepared, based upon the estimates of the cost of actual construction of similar works in other towns.

A small portion of Norwood lying near the Neponset River, and containing at present only a few scattered dwelling houses, is at such a low level that sewage from this area will probably have to be pumped in order to discharge it upon a suitable filtration area. It does not now seem likely that this territory will require sewerage for many years; but an estimate of the cost of collecting this sewage twenty years hence and pumping it to a filtration area has been made, and is included in the estimated cost of the disposal of the sewage of the town.

The sewage of a portion of the town of Norwood situated in the valley of Purgatory Brook cannot be disposed of in connection with the sewage of the main portion of the town without pumping. A portion of the town of Westwood is also in the valley of this stream, and the sewage of this territory would naturally be included with that of the portion of Norwood in the valley of the brook. The region is not thickly settled at present, though several new houses have been built near Ellis Station on the New England railroad within a few years, and it is possible that a considerable village may grow up in this neighborhood at some future time. The sewage can be disposed of by filtration upon land in the valley of Purgatory Brook, where there are ample areas well suited to the purpose, upon which the sewage can be discharged by gravity; or it can be pumped into the sewers of the main portion of Norwood, and disposed of in connection with the other sewage of the town. The cost of the disposal of the sewage of the Purgatory Brook valley by both plans has been estimated as carefully as practicable.

The estimated annual charges for interest and sinking fund upon the cost of works for conveying the sewage of Norwood, including the portions of Westwood that have been referred to, to the filtration area and purifying it, together with the estimated annual cost of maintenance, are given in the following table. These estimates

do not include the cost of interest and sinking fund or maintenance of such sewers in the towns as would be common to the various plans which have been considered.

1. Estimated annual cost of purifying the sewage of the main portion of Norwood only,	$3,157 00
2. Estimated annual cost of purifying the sewage of Norwood, including pumping the sewage from the low lands near the Neponset River, twenty years hence,	4,036 00
3. Estimated annual cost of disposing of all of the sewage of Norwood, including the cost of purifying the sewage of portions of Norwood and Westwood situated in the valley of Purgatory Brook, upon land in that valley,	6,242 00
4. Estimated annual cost of purifying all of the sewage of Norwood, including the portions of Norwood and Westwood in the valley of Purgatory Brook, if sewage from the latter valley should be pumped into the sewers of the main portion of Norwood,	9,468 00

Large quantities of waste products from manufactories, principally paper mills and tanneries, are discharged into the river at Walpole and Norwood. The quantity of water used in the paper mills at East Walpole in the preparation of stock is probably much greater than the quantity of sewage that would be collected from Walpole and Norwood at the present time. No provision has been made in the estimates for taking this paper mill sewage into the sewers, because it appears to be practicable and desirable, judging from investigations that have been made by the Board, to purify this waste liquor at the mills sufficiently to prevent serious pollution of the river. The tannery waste, however, can best be disposed of by receiving it into the sewers, and in this investigation the estimates of the probable quantity of sewage have been made sufficiently large, it is believed, to make due allowance for all manufacturing sewage that need be disposed of by discharging it into the sewers.

Sharon.

This town is very small, having a population at the present time of only about 1,940. It is to some extent a place of residence for people who do business in Boston, and is to a considerable extent also a summer resort. It is not likely to require sewerage for many years in the future. The main village is situated upon a hill between the valleys of Massapoag Brook and Beaver Hole Meadow

Brook, and nearly all of the population is situated upon this hill or near the upper end of the valley of Massapoag Brook.

An examination of the region shows that it is feasible to collect all of the sewage of the thickly settled portions of the town in sewers in the valley of each brook, which can be joined near the foot of the hill about a mile north of the village, and an ample area of land suitable for the purification of all of the sewage of the town for a very long time in the future can be found within the limits of the town not far from this place. There are several areas which might be used for the purpose. The probable annual cost to the town of the construction and maintenance of the purification works and main sewers, so far as they would differ from the sewers and works that would be constructed to connect the town with the Metropolitan system, is estimated to be $1,776.

Stoughton.

The estimated present population of this town is about 5,200. It is chiefly a manufacturing town, and the population is quite dense in the main village. All of the thickly settled portion of the town is within the Neponset River water-shed, and drains naturally into the valley of the Steep Hill Brook, a tributary of the east branch of the Neponset River, though a large part of the area of the town is within the water-shed of the Taunton River. An examination of the valley of this brook has been made, with a view to selecting a suitable place for the purification of the sewage of the town when sewerage shall be required, which seems likely to be the case before many years in the future.

Examinations show that it is desirable to select an area as far down the valley as practicable, since the population appears to be extending in that direction. The results of the investigations show that suitable filters can be constructed within the limits of the town, and in such a location that all of the sewage can be discharged upon them by gravity. An ample area appears to be available to provide for the disposal of the sewage for the next thirty or forty years. The estimated yearly cost of main sewers and other works for conveying and purifying the sewage during the next forty years, on a basis comparable with the works which would be necessary if the town should be connected with the Metropolitan district, is $4,000.

Canton.

The population of Canton at the present time is about 5,130. This town is, like Norwood, a manufacturing town, which also contains a considerable and increasing number of people who do business in Boston. The waters of four streams join to form the East Branch of the Neponset River in the southerly portion of this town, and the densely populated portions are nearly all situated near the junction of these streams. The sewage of all of the thickly settled part of the town can be readily collected in the valley of the East Branch, a short distance below the main village and not far from the Fowl Meadows.

An examination of lands in the region of the East Branch and along the Fowl Meadows has shown that it will be practicable to dispose of the sewage of Canton upon a filtration area well suited for the purpose, upon which the sewage can be delivered by gravity, and the indications are that an ample area can be secured for the purification of the sewage of Canton for the next thirty or forty years.

There is a small village in the valley of Ponkapoag Brook, from which it will probably not be practicable to convey the sewage to the filtration area which may be selected for the main portion of the town; and there are two other small valleys on the southerly side of the Neponset River, between the East Branch and the brook which flows through Ponkapoag Village, which will probably have to be excluded from any plan for the purification of the sewage of Canton, unless the sewage from these latter valleys should be pumped to the main sewers of the town. None of these areas require sewerage at the present time, and they do not seem likely to require it for many years in the future. If, when sewerage becomes necessary, it is not found to be practicable to pump the sewage into the main sewerage system of the town, the sewage can be collected at one place and purified without serious difficulty. There is so little likelihood that these districts will require sewerage for many years that no estimates of the probable cost of disposing of the sewage from these areas have been made. The annual cost of construction and maintenance of sewage-disposal works for the thickly settled portion of the town, not including local sewers common to all the plans considered, during the next forty years is estimated to be $6,565.

FEASIBILITY OF DISPOSING OF THE SEWAGE OF THE TOWNS OF THE UPPER NEPONSET VALLEY IN CONNECTION WITH THE SOUTH METROPOLITAN SYSTEM, AND PROBABLE COST OF WORKS.

It has been shown that it is probably feasible to purify the sewage of all the towns in the upper portion of the Neponset valley upon lands suited to the purpose, and in all but one case upon land located within the limits of the respective towns, for as many years in the future as the Metropolitan system of sewerage is designed to serve, and the feasibility and probable cost of disposing of the sewage of these towns in connection with the Metropolitan system will next be considered.

The topography of the Upper Neponset River valley in this region is such that any sewer laid to convey the sewage of the towns under consideration to the present Metropolitan sewer in Hyde Park, or that vicinity, or to the proposed new high-level sewer by gravity, will necessarily have to pass through the greater portion of the length of the Fowl Meadows, and be laid with very flat grades in order to be low enough to receive all of the sewage of the towns in question. If such a sewer should be built, it would, if the present plan of Metropolitan construction is carried out, be extended through the valley so as to provide a proper outlet for the sewage of the various towns into the main sewer at some convenient point or points near the boundary of each town.

Estimates have been made for a main sewer beginning at the boundary between Walpole and Norwood and extending down the valley of the Neponset River to the present Metropolitan sewer in Walnut Street, Hyde Park. A branch sewer from the boundary line between Stoughton and Canton would receive the sewage of Stoughton, and, passing through the valley of the East Branch, receive the sewage of all of the thickly settled portions of Canton, and discharge into the main sewer at or near Neponset Street. A small branch in the valley of Massapoag Brook would receive the sewage of Sharon and discharge it into the main branch in Canton. There would also be a branch in the valley of Purgatory Brook at some future time, extending from the Westwood boundary to the main sewer at some convenient point below Neponset Street.

The estimated cost of such a sewer with the branches to Stoughton,

Sharon and Walpole, and a small branch up the valley of Purgatory Brook to the Westwood line, is $673,430.

If the sewer should be constructed, the length of time during which the Metropolitan sewer below Walnut Street down to the high-level sewer would be sufficient to provide for the removal of the sewage discharged into it would be considerably reduced. The sewer is estimated at the present time to be of sufficient capacity to provide for the sewerage of the district up to 1930; but if the sewer through the upper Neponset valley should be constructed, it is probable that the capacity of the present Neponset valley sewer would be reached in 1923.

If the sewer should be built to connect with the present Metropolitan sewer, it could be extended from Walnut Street to the high-level sewer at some future time, that is, in 1923, or when the capacity of the Metropolitan sewer is reached. While a slight advantage in grades could be obtained by constructing the upper Neponset valley sewer down to the high-level sewer in the beginning, on the other hand, the cost of constructing a sewer in this way would be greater than to construct the sewer to the present Metropolitan sewer, and subsequently extend it to the high-level sewer when required in the future.

The comparative costs of the two schemes are estimated to be as follows: —

1. Cost of the upper Neponset valley sewer and branches to present Metropolitan sewer at Walnut Street, Hyde Park,	$673,430
Present worth of cost of sewer to be built in 1923 from Walnut Street in Hyde Park to proposed high-level gravity sewer,	61,200
Total,	$734,630
2. Cost of upper Neponset valley sewer and branches, if constructed in the beginning to connect directly with the high-level sewer,	$872,700
Excess of cost of Scheme 2 over Scheme 1,	$138,070

It would not seem necessary to expend the larger sum of money in order to secure the slight advantage of grade that would be obtained by the more expensive scheme of constructing down to the high-level sewer.

In order to determine the cost to each town in the upper Neponset valley of sewage disposal through the Metropolitan system, the

cost of the present Metropolitan sewerage systems in the Charles and Neponset valleys has been added to the probable cost of the high-level scheme as outlined by the Metropolitan Sewerage Commission, and to this sum has been added the estimated cost of a main sewer for the upper Neponset valley, together with branches to the various towns. It has been assumed that each town will pay toward interest and sinking fund for this cost of works in the proportion that its valuation bears to the entire valuation of the district. For the maintenance of the Metropolitan system an estimate has been prepared, using as a basis the cost of maintenance of present Metropolitan works as ascertained by the Metropolitan Sewerage Commission, and carrying it forward to the year 1910, and this cost has been apportioned to each town in proportion to its estimated population.

Upon the basis of these estimates, it is found that the percentage of cost of construction and of maintenance of the South Metropolitan sewerage system that the towns in the upper Neponset valley would pay for the collection and disposal of their sewage, at least during the first few years of the operation of the works, and the yearly cost to each of the towns, would be approximately as shown in the following table: —

Table showing Probable Yearly Assessment of Each Town in the Upper Neponset Valley and the Yearly Assessment of the Remainder of the District at about the Year 1910.

	Maintenance.	Construction.	Total.
South Metropolitan district,	$27,996	$276,809	$304,805
Canton,	495	3,372	3,867
Norwood,	600	2,766	3,366
Sharon,	144	1,094	1,238
Stoughton,	369	1,960	2,329
Walpole,	345	1,758	2,103
Westwood,	51	403	454
Totals,	$30,000	$288,162	$318,162

Bringing forward the estimated cost to each town of disposing of its sewage separately by purification upon land, as already given, and comparing the results with the estimated yearly cost to each town for disposing of its sewage in connection with the South Metro-

politan district, as given in the preceding table, it is found that the cost of disposal of the sewage of the various towns by each plan would be as follows: —

Town.	Yearly Cost of purifying Sewage upon Land.	Yearly Cost of disposing of Sewage in Connection with South Metropolitan District.	Yearly Saving by joining Metropolitan District.
Canton,	$6,565	$3,867	$2,698
Norwood and Westwood,*	9,468 or 6,242†	3,820	5,648 or 2,422†
Sharon,	1,776	1,238	538
Stoughton,	4,000	2,329	1,671
Walpole,	2,753	2,103	650
Totals,	$24,562 or $21,336	$13,357	$11,205 or $7,979

* Portion of Westwood. † With two filtration areas.

It will be seen from the above table that there would be considerable saving in annual cost to the various towns if a Metropolitan sewerage system should be built through the upper Neponset valley, with branches laid to the nearest point on the boundary lines of Westwood, Walpole, Sharon and Stoughton, provided that the main sewers are to be paid for by the whole district. The effect of admitting these towns upon the probable annual cost to the South Metropolitan district as now constituted is indicated by the following table: —

Estimated annual charge for interest and sinking fund to the present South Metropolitan district, for the year 1910,	$259,810
Estimated charge for maintenance in the year 1910,	29,000
	$288,810
Estimated annual charge for interest and sinking fund to the present South Metropolitan district in 1910, if upper Neponset River valley towns should be included in the district,	$276,809
Estimated annual charge for maintenance in 1910,	27,996
	$304,805
Estimated additional annual cost to be borne by the South Metropolitan sewerage district as now constituted, if upper Neponset valley towns are admitted into the district,	$15,995

It will be seen, then, that, if the upper Neponset valley towns are admitted to the district on the basis outlined above, the charges to the towns which now compose the district (by the act of 1899) would be considerably increased.

If the upper Neponset valley towns should pay the last-mentioned sum, that is, $15,995 per year, so as to relieve the district of extra expense for their sewerage, the aggregate yearly cost to those towns of connecting with the Metropolitan system would be $29,352, which would be considerably greater than the aggregate cost of purifying their sewage within their own limits (see table on page 60). The estimated cost for connecting the upper Neponset valley towns with the Metropolitan district does not include the cost of making the high-level sewer of larger size below the place where it would be joined by the Neponset valley sewer, in order to remove the sewage from the towns in the upper Neponset valley.

It is impracticable to tell whether the proportion of charges to the towns in the upper Neponset valley would become greater, as compared with the proportion of the whole district, or less, in the future than it is at the present time. So far as can be judged from present tendencies, the proportion of the expense of interest and sinking fund that these towns would bear as compared with the whole district would remain about as it would be at present.

It has already been indicated that, of the towns mentioned, Walpole and Sharon are not likely to require sewerage for a good many years, and it is doubtful whether sewers will be required in Stoughton for several years from the present time. But if these towns are to join the district, provision for receiving the sewage will have to be made at once, and the size of the proposed high-level sewer will have to be increased from the place where this sewage would enter to the outlet, so as to provide for receiving the sewage of these towns. It would only be equitable, in that case, that the towns should begin at the present time to pay something annually toward the cost of the sewer; and if these payments should be extended over a period of ten or possibly fifteen years, as might be the case with one or two of the towns, the payments and accumulated interest might amount to so much that there would be little or no saving in cost to the town of joining the Metropolitan system at present over the cost of building independent disposal works when sewers became necessary. Under these circumstances, there might be no saving to Sharon and Walpole, and possibly very little to Stoughton, by joining the Metropolitan district at the present time, as compared with the disposal of the sewage separately when sewerage becomes necessary. In Canton and Norwood, however, systems of sewerage

seem likely to be required within a short time. If a Metropolitan sewer should be built for the towns of Canton and Norwood alone, beginning at Neponset Street, and the main branches to Walpole, Stoughton and Sharon should be omitted, the towns of Canton and Norwood would have to build considerable lengths of sewer within their own territories that would otherwise be built by the Metropolitan district. Since there is much doubt as to the advantage to the three other towns from coming into the system, an estimate has been prepared of the cost to the two towns of Canton and Norwood of disposing of their sewage by purification, as compared with the cost of entering the Metropolitan system at Neponset Street. The results are shown in the following table: —

Norwood and Westwood.

Estimated yearly assessment of Metropolitan district in the year 1910,	$3,775
Estimated charge for interest and sinking fund on main sewer down to Metropolitan sewer at Neponset Street,	3,284
Estimated yearly cost to these towns if a Metropolitan sewer should be built to Neponset Street,	$7,059
Estimated cost to these towns with two independent filtration areas in 1910 (see page 60),	$6,242
Estimated cost to these towns with a single filtration area in 1910 (see page 60),	$9,468

Canton.

Estimated yearly assessment of Metropolitan district in 1910,	$3,814
Estimated charge for interest and sinking fund on main sewer down to Metropolitan sewer at Neponset Street,	2,071
Estimated yearly cost to Canton to connect with a Metropolitan sewer at Neponset Street,	$5,885
Estimated cost of filtration to Canton in 1910 (see page 60),	$6,565

It will be seen from the foregoing table that there would be no material saving in cost to these two towns (Norwood and Canton), taken together, to connect with the Metropolitan sewerage system, unless the other towns come into the system in the beginning, and sewers are laid by the district as a whole to the boundaries of the farther towns; and, if assessments should be paid for a few years before sewers are deemed necessary, the advantage of connecting with the Metropolitan system as regards cost would disappear. It

has been assumed in this estimate that the Metropolitan sewer would be built by the Metropolitan district as far as Neponset Street; but, if only Canton and Norwood are to come into the district, the sewer might not be built further than the Norwood boundary opposite Canton, which might be deemed a reasonable limit for Metropolitan construction; consequently, the towns of Canton and Norwood would have to build a sewer down to the Metropolitan sewer through their own territories.

It is obvious that, in this case, the cost to these towns of connecting with the Metropolitan system would be much greater than the cost of purifying their sewage independently within their own limits. It is also to be considered that, while, in the apportionments thus far made by the supreme court, the cost of main sewers and branches to the different towns has been assessed upon the district as a whole, it cannot be assumed that this method will be followed in the future, especially in a case like that of the upper Neponset valley, where a considerable burden of cost would be placed upon the district at large, by building Metropolitan sewers and main branches to all the towns in this valley, above the amount which would be collectible from these towns upon the basis of assessment followed hitherto.

The filtration areas which have been selected as the basis for the estimates of cost given in the preceding pages are located remote from populous districts, and are likely to afford satisfactory places of sewage disposal for many years in the future.

Recent experiments and investigations as to the purification of sewage indicate that it may be practicable to purify much larger quantities of sewage on a given area, if necessary, than has hitherto been found practicable, and smaller areas may be required than those upon which the foregoing estimates are based, but so far as can now be judged no material change in the cost of purification from the estimates given can be expected.

Considering all the circumstances, the most appropriate method of disposing of the sewage of the upper Neponset valley appears to be by purifying the sewage of the towns upon land; and it does not appear to be necessary or desirable to provide relief in the matter of sewerage for any of the towns in the Neponset valley, not now included in the Neponset valley Metropolitan district, in the new South Metropolitan system.

Conclusions as to Additional Relief required in the Charles and Neponset River Valleys.

The conclusions reached from a study of the probable future disposal of the sewage of the upper Charles and Neponset River valleys are, that only a few small areas in Wellesley and Needham, and possibly a small area in Weston, which are included in the portion of the drainage area of the Charles River tributary to that stream below Dedham, are likely to require sewerage in connection with Metropolitan works; and that the sewage of all other areas in these valleys not provided for by existing Metropolitan systems can be disposed of by independent works in each town, or possibly by the combination of two or more towns.

The population of the small areas which are likely to require sewerage in connection with Metropolitan works is very small at the present time, and in any case these areas are not likely to contain a population much larger than 12,000 by the end of the period for which the proposed high-level sewer is expected to serve.

ESTIMATED POPULATION OF PROPOSED HIGH-LEVEL AND BOSTON MAIN DRAINAGE DISTRICTS, AND ESTIMATED QUANTITIES OF SEWAGE.

Estimates of the probable future population of the area which it is proposed to make tributary to the high-level sewer, and of the probable quantity of sewage that may flow in the sewers of the high-level district, have been prepared on the basis already given, and the results are presented in the following table: —

Estimated Probable Future Population of the Area Tributary to the Proposed High-level Sewer, and the Probable Quantity of Sewage from this Population.

Year.	Estimated Population.	Estimated Quantity of Sewage per Capita per Day (Gallons).	Estimated Total Quantity of Sewage per Day (Gallons).
1900,	261,500	180.0	47,070,000
1905,	332,900	192.5	64,083,000
1910,	412,400	205.0	84,542,000
1915,	502,600	217.5	109,315,000
1920,	601,100	230.0	138,253,000
1925,	709,900	242.5	172,151,000
1930,	826,900	255.0	210,859,000
1935,	951,800	267.5	254,606,000
1940,	1,085,200	280.0	303,856,000

The foregoing estimate makes no provision for the disposal of storm water from this district. At the present time the large quantities of mingled sewage and storm water flowing from the combined systems of sewers in the proposed high-level district at times of rain are discharged into the Charles and Neponset rivers, or Muddy River, Stony Brook or other tributaries of the two main streams.

The capacity of the proposed high-level sewer as designed will for many years be much greater than the quantity of sewage which will be discharged into it from the proposed high-level districts; and it will be possible in the beginning to discharge into this sewer much larger quantities of storm water from the areas which are provided with sewerage upon the combined plan than it is practicable to receive from these areas into the Boston main drainage system at the present time.

An estimate of the quantity of storm water which might be received into the high-level sewer in the future from the areas served by the combined systems in the South Metropolitan district, which aggregate 18.6 miles, is given in the following table: —

Year.	Capacity for Storm Water (Gallons per Day).	Run off from District (Inches in Twenty-four Hours).	Year.	Capacity for Storm Water (Gallons per Day).	Run off from District (Inches in Twenty-four Hours).
1900, . .	256,870,000	.79	1925, . .	131,705,000	.41
1905, . .	239,773,000	.74	1930, . .	92,997,000	.29
1910, . .	219,314,000	.68	1935, . .	49,250,000	.15
1915, . .	194,541,000	.60	1940, . .	-	-
1920, . .	165,603,000	.51			

It will be seen from the foregoing table that for about five years the high-level sewer would be capable of removing, in addition to the average quantity of sewage discharged into it, a rainfall of a little more than three-quarters of an inch per day over the areas in which the sewers receive both sewage and storm water, if the tributary sewers were capable of receiving and delivering so large a quantity of sewage. In subsequent years, as the flow of sewage becomes greater, the quantity of storm water that can be admitted to the main

sewer will continually decrease and the quantity of mingled sewage and storm water that would be discharged into local water courses would increase, and it will become necessary, in order to prevent the discharge of sewage through overflows in very small rains and thaws, to separate the sewage from the storm water throughout the district, and to provide some other method of disposing of the storm water.

Sewage overflows from combined systems of sewers in the high-level district will necessarily discharge into smaller streams and bodies of water than in the case of the main drainage system of the city of Boston, and such overflows are likely to become very objectionable in the high-level district, as the density of the population in the district increases.

The act providing for the construction of the high-level sewer already referred to includes a provision that "the sewerage systems of all drainage districts not now drained by the South Metropolitan system which are constructed after the passage of this act shall be constructed in accordance with the so-called separate system of sewerage." It seems important not only that this provision should be carried out but that it should be supplemented by the separation of the sewage from the storm water as soon as practicable in the districts now served by the combined system which will be connected with the proposed high-level sewer, in order that the pollution of the inland waters in the district at any time by the discharge of sewage can be prevented. This separation of the sewage from the storm water can probably be made without special difficulty, and, as it can be done gradually, the cost will not be a serious financial burden to the municipalities in the district in which the combined systems now exist.

After the completion of the high-level sewer there would remain an area of about 12 square miles, including the main portion of Boston and low areas along the harbor front and along Stony Brook, which would still be tributary to the present Boston main drainage system, which is the area that those works were expected ultimately to serve. The estimated population of this area in the future and the probable quantity of sewage that will flow into the sewers are given in the following table: —

Estimated Probable Future Population of the Main Drainage District and the Probable Quantity of Sewage from this Population.

Year.	Estimated Population.	Estimated Quantity of Sewage per Capita per Day (Gallons).	Estimated Total Quantity of Sewage per Day (Gallons).
1900,	341,000	180.0	61,380,000
1905,	362,100	192.5	69,704,000
1910,	382,900	205.0	78,494,000
1915,	399,600	217.5	86,913,000
1920,	414,700	230.0	95,381,000
1925,	427,500	242.5	103,669,000
1930,	440,100	255.0	112,225,000
1935,	448,400	267.5	119,947,000
1940,	453,800	280.0	127,064,000

The quantity of storm water that these works will care for, when the quantity of sewage is not greater than the average daily flow, after the high-level sewer is built, will be approximately as given in the following table, assuming that the capacity of the main drainage works will be increased to 154,000,000 gallons per day: —

Year.	Capacity for Storm Water (Gallons per Day).	Run off from District (Inches in Twenty-four Hours).	Year.	Capacity for Storm Water (Gallons per Day).	Run off from District (Inches in Twenty-four Hours).
1900,	92,620,000	.44	1925,	50,331,000	.24
1905,	84,296,000	.40	1930,	41,775,000	.20
1910,	75,506,000	.36	1935,	34,053,000	.16
1915,	67,087,000	.32	1940,	26,936,000	.13
1920,	58,619,000	.28			

It will be seen from this table that for many years after the high-level area is diverted the main drainage works will be capable of receiving storm water under average conditions at a greater rate than was provided for in their original design, but they cannot be depended upon to take a quantity of storm water so large as indicated in the table at times of maximum flow of sewage and leakage. The quantity of storm water that can be received into the main drainage sewers will become gradually smaller in the future with the growth of the city, and the quantity of sewage discharged through storm overflows will gradually increase; and, in order to prevent the pollution of the waters about the city by large quantities of sewage,

it will become necessary, before many years, to provide means for the proper disposal of the storm water.

It is obviously desirable that, whatever means of relief is provided for the main drainage works, a sufficient portion of the area now tributary to the works should be diverted, to prevent the necessity of duplicating the tunnel and other expensive portions of the works at any future time.

In the original design of the works it was expected that they would, after the diversion of the higher districts, be of sufficient capacity to serve indefinitely an area of about 12 square miles of the densely populated portion of the city, including the business portion, but allowance was made for the possibility that they might be required to serve a slightly larger area. It is impossible to estimate satisfactorily the quantity of sewage that may be produced in the business portions of the city in the future. A great increase in the size of buildings and number of people who occupy them is constantly going on. Dwelling houses are gradually giving place to large buildings which are not dwelling places, but are in most cases occupied by as large and often a larger number of people during a portion of the day than were the dwelling houses which they have replaced. In providing relief by a high-level or other sewer for the districts under consideration, it seems necessary to make a provision for a continued increase in the quantity of sewage that will be produced in the areas that were expected to be served indefinitely by the main drainage works at least equal to that which is made for other portions of the city.

While the above tables serve to indicate what the future population of these districts may be, as judged by past experience and present tendencies, and the approximate quantities of sewage that may flow into the sewers of these districts, the actual results may be quite different from those which are now anticipated; but the proposed line of the division of the district now tributary to the main drainage works appears to be a reasonable and satisfactory one, so far as the probable future requirements of the areas under consideration in the matter of sewage disposal can be foreseen at the present time. If provision shall be made for removing the ultimate quantities of sewage, as estimated in the two foregoing tables, the works will be sufficient to provide for the removal of the sewage of these districts as a whole for a very long time in the future, and it will

be practicable to divert the sewage from portions of either district into the works of the other district, if it should become desirable to do so in the future, probably at no great expense.

OUTLET FOR PROPOSED HIGH-LEVEL SEWER.

In the original design of the Boston main drainage system, as already stated, provision was made for disposing of the sewage of the future high-level sewer at Moon Island, in connection with the sewage from the areas connected with the pumping system. Sewage has now been discharged at the Moon Island outlet for a period of sixteen years, and the average quantity discharged in the year 1899 was 77,000,000 gallons per day. Recently the sewage of the city of Quincy has been discharged at this outlet.

Observations upon the discharge of sewage at this outlet were made in 1898, under the direction of the Metropolitan Sewerage Commission; but since that time additional reservoir capacity has been provided, and other observations have been made under somewhat different conditions. The necessity for discharging considerable quantities of sewage before high tide, and for continuing the discharge nearly until low tide, during the period covered by the observations made by the Metropolitan Sewerage Commission, apparently affected somewhat the distribution of the sewage over the harbor in this neighborhood, and caused it to be present in places where, if it had been discharged only on the earlier portion of the outgoing tide, — the time proposed when the works were designed, — sewage would probably not have been visible at any time.

Sewage from this outlet is discharged practically at the level of the sea, with a considerable velocity. After leaving the outlet it generally moves toward the southerly side of the shoal known as Sculpin Ledge, spreading across the harbor current. It then gradually bends to the eastward, under the influence of the tide, and the northerly limit of the sewage passes around the southerly end of Long Island. Sometimes a small sewage area lies along the north-westerly side of Long Island, and it is possible that at times some of the sewage passes out of the harbor on that side of Long Island; but under ordinary conditions no sewage passes out of the harbor in that direction when the sewage is discharged at the usual time, — that is, in the first two or three hours of the

outgoing tide. The southerly limit of the sewage tract appears generally to be along a line drawn from the southerly side of Moon Island in a south-easterly direction toward Hangman's Island; but about 4,000 feet south of the southerly shore of Long Island this line gradually bends to the north-east and passes south-east of Rainsford Island. The observations generally show that the sewage has become so thoroughly diluted by the time that it has travelled a little beyond Rainsford Island that it is unrecognizable.*

The present flow of sewage discharged from the reservoirs at Moon Island during the second and third hours of the outgoing tide passes out of the harbor south of Long Island, and becomes thoroughly mixed with the water of the harbor and does not return on the incoming tide. The best results are secured when the sewage is discharged into the most favorable currents, and the discharge of sewage into less favorable currents has led to unsatisfactory results and an accumulation of matters from the sewage in the region about the outlet. It is not desirable to begin the discharge of large quantities of sewage much before one hour after high tide, and it is not desirable to continue it much beyond the end of the fourth hour after high tide. It will probably be even more important to observe these limits when it becomes necessary to discharge much larger quantities of sewage.

The mingling of the sewage with the water takes place all over the area covered by the sewage, but goes on more rapidly near the edges of the area than elsewhere. The sewage remains quite close to the surface of the water, which is covered for a time with a greasy film. This film appears to be very thin, and it sometimes extends considerably beyond the area otherwise affected by the sewage. It is apparently composed of grease or oil from the sewage, and it is most noticeable on calm days, being quickly broken up by waves.

The observations indicate that, the greater the quantity of sewage that is discharged from the reservoirs, the greater will be the area of the harbor that will be covered with sewage, and the area covered will apparently increase in more than direct proportion to the quantity of sewage discharged. It is not likely that any considerable proportion of the sewage would pass out of the harbor north of Long Island, on account of the adverse currents at this place; and sewage discharged into the current which passes on the northerly

* The area in which sewage matter is observable at present outlets is indicated on the diagram opposite page 88.

side of Moon Island will nearly all run out south of Long Island, if the discharge of sewage is made only in the earlier and middle portions of the outgoing tide. If the quantity of sewage discharged at Moon Island shall increase in the future, the observations indicate that the enlargement of the area covered by sewage will be in a direction south or east of the limits of the area covered with sewage by the present discharge.

The results of the observations and experiments at Moon Island lead to the conclusion that considerably larger quantities of sewage than those discharged at this outlet at present can safely be discharged here in the future. But with the present quantities the sewage has been found to be recognizable for nearly two hours and a half after the discharge at the outlet has ceased; and, if the great quantity of sewage that would be conveyed by the proposed high-level and main drainage sewers combined should be discharged at this outlet in the future, it is evident that a very large area will be covered by sewage, and its dilution and dispersion might not be satisfactory.

It seems evident that it will be necessary to limit the quantity of sewage discharged at this outlet in the future, and to provide another outlet for a portion of the sewage from the districts which are connected with the main drainage system. The fact that smaller quantities of sewage discharged into the harbor do not cover so great an area in proportion to the quantity as do the larger quantities, is an indication that, by discharging a given quantity of sewage at two or more different outlets, the sewage will more quickly mingle with the sea water and cover a smaller aggregate area than would be the case if the whole quantity should be discharged at one outlet.

The great advantage of discharging sewage continuously and in comparatively small quantities into a large volume of tide water, as compared with discharging it in large quantities from reservoirs in a limited time, is well illustrated by a comparison of the conditions at the present outlets at Moon Island and at Deer Island. At Moon Island a large area is covered densely with sewage during a period of several hours at each tide, while at Deer Island the sewage flows in different directions at different parts of the day, covers a much smaller area, and becomes more readily broken up and mingled with the sea water.

In the investigations made with reference to the disposal of sewage into Boston harbor in previous years, many possible sewer outlets

were considered in addition to the two which have thus far been selected, — Deer Island and Moon Island, — and the results of these investigations will be briefly referred to. The places investigated by the first commission which examined Boston harbor with reference to the disposal of sewage included five possible outlets beside Moon Island. One of these was in Charles River; another was at City Point; the third, at Commercial Point, at the mouth of the Neponset River; the fourth, at a point in Dorchester Bay near the sewage pumping station; and the fifth, at Castle Island. All of the points mentioned are so close to the city as to be out of the question as places of sewage disposal at the present time.

In the final report on the main drainage system, just previous to its construction, the outlets considered, beside Moon Island and Castle Island, referred to above, were Spectacle Island and Thompson's Island. Regarding Spectacle and Thompson's islands the engineer's report states that Spectacle Island is evidently inferior either to Castle or Moon Island, and that Thompson's Island does not offer a favorable point for discharge.

The outlet for the proposed high-level sewer recommended by the Metropolitan Sewerage Commission in its report to the Legislature of last year, after numerous studies had been made of the currents of the harbor in this neighborhood, was into the harbor near the south-westerly end of Peddock's Island. Along the north-west side of Peddock's Island there is a wide and deep channel, in which it was found that the velocity of the current is nearly as great as at the sewer outlet at Deer Island, where the results in the disposal of sewage have been very satisfactory; and it was proposed to discharge the sewage through pipes laid on the bottom of the harbor at two points in this channel about 950 feet apart, distant respectively 3,500 feet and 2,750 feet from Nut Island, where the depth of water at low tide is more than 30 feet.

Nowhere else, in the portion of the harbor which it is feasible to reach by the proposed high-level gravity sewer, are the conditions in regard to depth of channel and volume of current so favorable for the dispersion and complete removal of the sewage before it reaches any inhabited shore as exist north-westerly from Peddock's Island; and very thorough investigations have been made to determine the probable course that would be taken by sewage discharged in this neighborhood, and the area over which it might be visible, with the

quantity of sewage that is likely to be discharged from the proposed high-level sewer.

The float experiments made by the Metropolitan Sewerage Commission included five points, of which the two which were deemed to be most satisfactory, as stated above, were located respectively 3,500 feet and 2,750 feet north of Nut Island. An examination of the results of these investigations, taken in connection with observations upon the discharge of sewage at existing outlets, indicated that some advantage might be obtained by discharging the sewage at a greater distance from the main land; and further investigations have been made in the neighborhood of Peddock's Island during the past year, with a view to removing the path of the sewage as far as practicable from the inhabited shores of Quincy, Weymouth and Hingham, to avoid danger that sewage might reach those shores, and at the same time avoid the danger of sewage entering Hull Gut in such a way as to lodge upon the shores of Hull. These investigations were made during the months of August and September of the year 1899. After an examination of the results of previous investigations, and a study of the channels and currents of the harbor, two points were selected which appeared to be the most favorably situated for the disposal of the sewage. These points were on opposite sides of the main channel leading to the Nantasket Roads, one mile from Nut Island and about 1,500 feet apart.

Since it has been found, from investigations at existing sewer outlets, that much of the sewage, after being discharged, remains near the surface of the water until it disappears, it was decided, in the investigations made in 1899, to use much shorter floats than those used in previous investigations. The length of most of the floats was about 8 inches, and of the remainder 2 feet. A large number of observations of the movements of floats started from the points described have been made, and the paths of more than 100 floats have been plotted upon charts of the harbor.

The results of the observations show in general that at high tide the current from the points selected for the observations sets out slowly through Nantasket Roads, and afterward much more rapidly, and this rapid current continues nearly until low water. With the turn of the tide the flood current from both points sets around the south-westerly end of Peddock's Island into Hingham Bay. This current is also rapid, though its velocity is somewhat less than that

of the ebb tide. Part of the floats set off in the first four hours of the flood tide passed close to Prince's Head, and then turned toward the north-east; another portion went toward Sheep Island in an easterly direction; and others, after reaching the neighborhood of Pig Rocks Beacon, turned to the south toward Weymouth Fore River. The experiments were made under all the varying conditions of wind and tide that occur in the summer and autumn seasons, and special attention was paid to the effect of easterly and north-easterly winds, which might carry the sewage toward Quincy Bay and the shores of Hough's Neck. In no case, even in strong easterly and north-easterly winds and at the most favorable time of the tide, did any of the floats started from the points selected move any considerable distance into Quincy Bay. Floats went in that direction only under the influence of very strong easterly winds, and then at so slow a rate that, even when started just after low water, it was found that they could not come near any shore before the turn of the tide.

The portion of the main land to which the floats approached most nearly was the beach on the easterly shore of Hough's Neck. Under ordinary conditions the floats did not come nearer than about 1,000 feet from this land. During the prevalence of strong north-easterly winds some of the floats approached within about 500 feet of the main land in the neighborhood, but not until two hours or more after leaving the starting point.

The results of the float experiments at Peddock's Island, when considered in connection with observations which have been made upon the discharge of sewage from Deer Island and from Moon Island, show very conclusively that sewage discharged at the points selected near the south-westerly end of Peddock's Island on the first four hours of the outgoing tide, in quantities as great as those which might finally be brought there by the proposed high-level sewer, will not touch or approach near any inhabited shore, but will be carried to sea and will not return.

The volume and velocity of the currents at Peddock's Island closely resemble the conditions at Deer Island, where very satisfactory results have attended the disposal of large quantities of sewage discharged in a *continuous* stream at all stages of the tide. A comparison of the results of the original float experiments at Deer Island with recent observations upon the area of the waters of the

harbor affected by the discharge of sewage at that point shows that the float observations indicated in a reliable way the direction which the flow of sewage would take at all times of the tide.

Comparing the conditions at Peddock's Island with those at Deer Island, it is seen that in both cases the current of the outgoing tide has a rapid velocity and is well concentrated for a long distance. Sewage discharged into the ebb current at Peddock's Island would, however, probably spread less than sewage discharged into the ebb current at Deer Island, because the channel at Peddock's Island is somewhat more confined. On the incoming tide, however, there is a considerable difference between the currents at the two places. At Peddock's Island a rapid current sets in at the turn of the tide and flows around the southerly end of that island into Hingham Bay, as already described; whereas at Deer Island the current is slower, and sewage has a tendency to remain in a large eddy south-west of Deer Island until it becomes mingled with the water. The observations upon the discharge of sewage at Deer Island show that the sewage is carried to a somewhat greater distance on the ebb tide than upon the flood, but is confined to narrower limits, and the ebb tide conditions at Deer Island are evidently quite similar to both flood and ebb tide conditions at Peddock's Island. The area covered with sewage when discharged on the ebb tide from the Deer Island outlet is about 1¼ miles in length and about two-fifths of a mile in width at the widest place, and aggregates about 250 acres in area under average conditions, when the sewage is being discharged at a rate ranging from 2,000,000 gallons to nearly 3,000,000 gallons per hour. This includes the area over which any sewage matter is visible.

Considering the results of the observations at Deer Island in connection with the numerous float experiments at Peddock's Island, it seems evident that, if a quantity of sewage amounting to 3,000,000 gallons per hour should be discharged *continuously* at each of the two points off Peddock's Island at which the observations by the State Board of Health were made, the sewage would not approach within a quarter of a mile of the main land at any point, or near any other inhabited shore, before becoming broken up and so dispersed as to be unrecognizable. In heavy north-east winds the floats came nearer the main land than under ordinary conditions; but, on the other hand, it has been found that sewage breaks up and disperses very quickly in a rapid current with any considerable velocity of wind.

It is not likely, judging from the experience at Deer Island, that with a discharge of sewage amounting to 3,000,000 gallons per hour at each outlet the discoloration of the sea water would be marked beyond a distance of 3,000 feet from the outlets, or that the odor of the sewage would be noticeable except in the immediate neighborhood of the outlets.

It is not practicable to determine definitely, from observations of the quantity of sewage now discharged at Deer Island, how large an area may be covered by sewage at Peddock's Island toward the end of the time for which the high-level sewer is designed to serve. After the high-level sewer is built, it will probably be several years before the quantity of sewage delivered at this outlet will be sufficient to be noticeable except in the immediate neighborhood of the two points of discharge; and a rate of discharge as great as 3,000,000 gallons per hour at each point, or a total flow of 6,000,000 gallons of sewage per hour, at the proposed outlet, does not seem likely to be reached for more than twenty years.

It is possible that, with the greater quantities of sewage that may be discharged from the high-level sewer toward the end of the period for which it is designed to serve, it may be found desirable to limit the quantity of sewage discharged on the flood tide and to discharge a larger proportion on the ebb tide. If such a plan should be found necessary, reservoirs can be built on Peddock's Island and a portion of the flow during the flood tide retained and discharged on the ebb tide; but it does not seem likely that such a provision will be found necessary for many years, if at all.

It might also happen, when large quantities of sewage are discharged in the future, that unsightly floating matters from the sewage might be driven by the wind upon some of the neighboring shores; but provision is made, in the plan proposed by the Metropolitan Sewerage Commissioners, for screening the sewage before it is discharged, and if further removal of floating matters should become necessary, provision can be made for retaining them in the sewer, or in a chamber built for the purpose, during the incoming tide, and discharging them only upon the outgoing tide, when they would be carried to sea.

The investigations lead to the conclusion that the discharge of the sewage from the proposed high-level sewer in a continuous stream as it flows from the sewer into the sea at the points at which the re-

cent observations have been made will effectually and satisfactorily dispose of this sewage, since it will quickly become thoroughly diluted in a very large volume of water, and carried to sea before it can create a nuisance or lodge upon any inhabited shore or other place where it might be objectionable, and that the proposed outlet is the best place of disposal for the sewage of the proposed high-level sewer that it is practicable to adopt.

OTHER AREAS WHICH MAY REQUIRE RELIEF BY A METROPOLITAN SYSTEM.

The resolve under which the investigations herein reported have been made requires the Board to report a plan for an outlet for a high-level gravity or other sewer for the relief of the Charles and Neponset River valleys; but it has seemed desirable to consider also the possible needs with respect to sewerage of certain contiguous districts which are likely to require sewerage before long, and which may require relief by the system proposed for the Charles and Neponset River valleys.

The Neponset River valley includes a portion of the city of Quincy, and works already constructed provide for the disposal of the sewage of this city into the present outfall sewer of the Boston main drainage system at Squantum; but in the future it is intended to discharge the sewage of Quincy into the proposed high-level sewer. South of the Neponset River valley and the city of Quincy, and along the southerly shore of Boston Bay, there is a large and growing population in the towns of Braintree, Weymouth and Hingham, in which sewers have not yet been constructed.

An examination of the topography of this region shows that there are three principal tributaries to Boston harbor in the towns referred to which also drain portions of other towns. Easterly from Quincy the first drainage area is that of the Monatiquot and Weymouth Fore rivers, which drain an area of 36.8 square miles above Ferry Point, between Quincy and North Weymouth. Included in this drainage area are the thickly settled portions of the towns of Randolph, Holbrook and Braintree, together with a populated portion of Weymouth and a small portion of Quincy. Very small portions of Milton, Canton, Stoughton, Avon, Brockton and Abington are also included in this water-shed.

East of the Monatiquot River is the drainage area of the Weymouth Back River, containing a large population in the villages of East Weymouth and South Weymouth, and including small and sparsely inhabited portions of Abington, Rockland, Hingham, Braintree and Holbrook. Further east is the town of Hingham, the thickly settled portions of which are located partly on an arm of Hingham harbor and partly in the drainage area of the Weir River, which discharges into Boston harbor west of the southerly end of Nantasket Beach.

The population of the principal towns in this region since 1865 and an estimate of their probable future population up to 1940 are given in the following table: —

Population by Census Returns.

Year.	Braintree.	Hingham.	Holbrook.	Randolph.	Weymouth.
1865,	3,725	4,176	–	5,734	7,975
1870,	3,948	4,422	–	5,642	9,010
1875,	4,156	4,654	1,726	4,064*	9,819
1880,	3,855	4,485	2,130	4,027	10,570
1885,	4,040	4,375	2,334	3,807	10,740
1890,	4,848	4,564	2,474†	3,946†	10,866
1895,	5,311	4,819	2,298	3,694	11,291

Estimated Future Population.

1900,	6,170	5,320	2,610	3,990	11,920
1910,	8,380	6,610	3,470	4,540	13,820
1920,	11,460	8,820	4,495	5,590	16,590
1930,	15,810	11,410	5,780	7,200	20,210
1940,	21,340	14,530	7,490	9,300	24,980

* Part established as Holbrook in 1872. † Part annexed to Avon in 1889.

Besides the permanent population in the towns referred to, there is a large and growing summer population along the shores of the towns of Weymouth and Hingham, and small sections in this region are already in need of sewerage, and the sewerage of some of the more densely populated areas will probably soon require consideration. The shores in this region are bordered in most places by very extensive areas of flats, which are bare at low water; and it is evident that to dispose of the sewage of areas which seem likely soon to require sewerage by discharging it into neighboring tide

waters will be likely to produce serious nuisances along the shores in this region, unless the sewage is conveyed to a sufficient distance to avoid the danger of its returning upon them. Owing to the situation of the thickly settled districts, a large proportion of which are close to the level of tide water, it will be necessary to pump the sewage in order to deliver it at any considerable distance from the shore.

The possible methods of providing sewerage for these towns has therefore been considered to determine whether it may be desirable to provide for the disposal of the sewage in connection with the high-level system or outlet.

Randolph.

The estimated population of the town at the present time is about 4,000. The population is located principally in one main village, but this population is nowhere very dense, and the denser portion covers a district over two miles long by fully a mile in width. There are several large shoe factories in the town, and it is to some extent a place of residence for persons doing business in Boston.

An examination of the town shows that it is practicable to collect nearly all of the sewage at a place in the vicinity of North Street near Pleasant Street, and to discharge it upon low land having a gravelly soil near the Monatiquot River east of the point referred to. This area is extensive, and is capable of disposing of a much greater quantity of sewage than is likely to be produced in Randolph for several years. A small area in the northerly part of the town cannot be drained to this place, and this area will have to be considered in connection with the sewerage of the valley of the Blue Hill River. Before considering further the disposal of the sewage of this town, reference will be made to the disposal of sewage for Holbrook.

Holbrook.

This town has an estimated population at the present time of about 2,600. It is possibly to some extent a place of residence for persons doing business in Boston, but is chiefly a manufacturing town, the principal industry being the manufacture of shoes.

An examination of the topography of the town shows that it is feasible to collect all of the sewage of the thickly settled portions which are likely to require sewerage for many years in the future in

the valley of the Monatiquot River near the north-westerly corner of the town. From a general study of the region it seems probable that the sewage of Holbrook can best be disposed of by purification, in connection with the sewage of the town of Randolph, upon the area of land referred to in the valley of the Monatiquot River. This area is nearly level, and is so situated that the sewage of practically all of the districts in the valley above can be delivered upon it by gravity. If suitable soil is not found over the whole of this area, excellent gravel can be obtained from higher lands contiguous to this territory; and the examinations show that an ample area of filter beds for the purification of the sewage of both towns can be prepared in this region.

An estimate of the probable cost of the disposal of the sewage of Randolph and Holbrook for the next forty years by purification upon land in the valley of the Monatiquot River is as follows: —

Annual cost to Randolph,	$2,200
Annual cost to Holbrook,	1,820

Braintree.

The estimated population of this town at the present time is 6,170. Nearly all of the thickly settled portions of the town are within the valley of the Monatiquot River and of its tributary the Blue Hill River. The Blue Hill River rises just within the limits of Canton, and flows along the southerly side of the Blue Hill range to the Monatiquot River near South Braintree. The greater part of the water-shed of the Blue Hill River above the point where it enters the town of Braintree is included in the Blue Hill reservation of the Metropolitan park system, but a small area in the valley of the river in Randolph is not included in that system. This area, however, is remote from any railroad, and does not seem likely to become populated to such an extent as to require sewerage for a long time in the future. Near the westerly boundary of Braintree is Great Pond, which is used as a source of water supply for Randolph and Holbrook. A portion of this water-shed is thickly settled, but most of the thickly populated portion can be provided with sewerage in connection with the Randolph system outlined above. The remaining portion, having an area of a little over a square mile, will probably have to be provided with sewerage,

when sewerage is required, in connection with a sewer in the Blue Hill River valley, but this region also is not likely to require sewerage for many years.

The northerly portion of the town of Braintree lies within the valley of Town River, which discharges into Town River Bay through the city of Quincy. The sewage of nearly all of this section of Braintree, including an area of about 1.95 square miles, can be disposed of in the future in connection with the Quincy system by gravity, or else it will have to be pumped into Braintree sewers when such sewers may be constructed. The district already contains a considerable population, and the population is likely to increase rapidly in the future.

The greater portion of the population of the town of Braintree is contained in the villages of South Braintree, Braintree and East Braintree, which lie within the valley of the Monatiquot River. To provide for the sewerage of these villages it will probably be found necessary to construct a sewer through the valley of the Monatiquot River from South Braintree to East Braintree, from which place the sewage will have to be pumped to a place of purification or to some suitable place of disposal in the harbor. The problem of the disposal of the sewage of this town is one of much difficulty; and, so far as investigations have been made, it is likely that it will be found desirable to find a suitable sea outlet for the sewage, if possible, since there does not appear to be any suitable area available for the purification of the sewage of the town without pumping to a considerable elevation and for a long distance.

Weymouth.

The estimated population of this town at the present time is 11,920. The chief centres of population are Weymouth, East Weymouth and South Weymouth. The village of Weymouth is in the valley of the Monatiquot River, close to the boundary between Weymouth and Braintree. The villages of East Weymouth and South Weymouth are within the valley of Mill River, which discharges into the Weymouth Back River. The village of Weymouth is situated so close to Braintree that there will be much advantage in providing for the sewerage of Braintree and this portion of Weymouth by one plan.

The sewage of the villages of East Weymouth and South Wey-

mouth would naturally be collected near the level of tide water at the head of Weymouth Back River.

There does not appear to be any suitable place in the neighborhood of the Weymouth Back River, in Weymouth, which might be used for the purification and disposal of the sewage of the town, though it is possible that by the use of systems of rapid filtration the sewage could be purified in this neighborhood for several years. It is probable that a suitable area can be found for the purification of the sewage in the southerly part of the town, and it would be feasible to pump the sewage to such an area. The cost of either of these plans, however, would probably be large.

Considering the circumstances, it seems desirable that the sewage of the towns of Weymouth and Braintree should be disposed of together, since in this way the expense to each town is likely to be greatly reduced. It will probably be feasible to purify the sewage of these towns by some system of rapid filtration, even if suitable soil for filtration cannot be found within their limits; but pumping will probably be necessary in order to dispose of the sewage by any plan, and the cost of works for purifying the sewage would be likely to be much larger than the cost of a suitable sea outlet, if such an outlet could be reached within a reasonable distance.

The proposed high-level gravity sewer appears to afford a means by which the sewage of these towns can be conveyed to a suitable outlet at a reasonable expense, and an investigation has been made to determine the probable cost of conveying the sewage of these towns to that sewer.

Hingham.

The estimated population of this town at the present time is 5,320. The thickly settled portion of the town is located not far from the head of Hingham harbor, but there is also a considerable population in the valley of the Weir River in the easterly part of the town. The greater portion of the population is so located that the sewage of the town will have to be collected close to the level of tide water, and disposed of, as in the case of Weymouth and Braintree, by pumping it either to a suitable harbor outlet or to some place where it can be purified. As in the case of Weymouth, there is a considerable area of shore lands in Hingham which are likely to become thickly settled before many years, and there are extensive areas of flats along the shore of the harbor in front of the town; so that the

sewage, if discharged into the sea, will have to be conveyed to a considerable distance from that shore, in order to avoid danger of creating a nuisance upon these flats.

The proposed high-level sewer appears to offer a satisfactory means of sewage disposal for Hingham as well as for the other towns mentioned, and the disposal of the sewage of this town in connection with the high-level sewer has been considered.

MEANS BY WHICH BRAINTREE, WEYMOUTH AND HINGHAM MIGHT BE PROVIDED WITH AN OUTLET FOR SEWAGE INTO THE PROPOSED HIGH-LEVEL SEWER, AND THE PROBABLE COST OF WORKS.

The results of investigations have shown that it is feasible to collect all of the sewage from nearly all of those portions of the towns of Weymouth and Hingham which drain toward Boston harbor into a main sewer, which would begin near the Weir River in Hingham near the point where the river is crossed by Leavitt Street, and passing through streets and private lands in a westerly direction, generally in the neighborhood of the main highway from Cohasset to Quincy, would convey it to a pumping station on the westerly shore of the Weymouth Fore River near Ferry Point, from which the sewage would be pumped through a force main and discharged into the proposed high-level sewer at a point about two miles above its outlet. A branch sewer from South Weymouth through East Weymouth to the main sewer near the Weymouth Back River would convey the sewage of those villages to the main sewer; and another branch sewer, beginning near South Braintree and following the valley of the Monatiquot River and along the westerly bank of the Weymouth Fore River, would receive the sewage of the villages of South Braintree, Braintree, East Braintree and Weymouth, and convey it to the pumping station near Ferry Point. This sewer might be extended further up the valley from South Braintree and receive the sewage of Randolph and Holbrook, if deemed desirable.

It is possible that sewerage might not be deemed necessary in Hingham for a considerable time after it was found essential in Braintree and Weymouth; and for this reason an estimate of the cost to Braintree and Weymouth alone of disposing of their sewage into the high-level sewer by this plan has first been considered. In this estimate it has been assumed that the South Metropolitan district

would build a pumping station on the westerly side of the Weymouth Fore River near Ferry Point, and a force main through which to force the sewage to the high-level sewer. It is also assumed that the Metropolitan district would build a sewer along the westerly shore of the Weymouth Fore River from Ferry Point to the southerly side of Heywood's Creek, which is just within the limits of Braintree, to receive the sewage of Braintree and the main village of Weymouth; and a sewer across the Weymouth Fore River to its northerly or easterly shore within the limits of Weymouth, to receive the sewage of East Weymouth and South Weymouth.

The estimated total cost of these works, the yearly cost to each town, and the yearly extra expense brought upon the South Metropolitan district above the amount that would be received by the assessments upon these towns if the system of apportionment hitherto used should be followed at about the year 1910, are as follows: —

Total cost of works,	$174,550
Annual cost to Braintree for assessment for interest, sinking fund and maintenance about the year 1910,	4,060
Annual cost to Weymouth for assessment for interest, sinking fund and maintenance about the year 1910,	5,974
Extra annual cost, at about the year 1910, to South Metropolitan district of building and maintaining works for admitting these two towns,	916

If Hingham should be included in the proposed plan, and a sewer extended from the end of the Weymouth Branch sewer to the easterly side of the Weymouth Back River, and the other portions of the works built of a sufficient size to receive the sewage of Hingham in addition to the other towns, the cost to the three towns and the South Metropolitan district might be about as follows: —

Total cost of works,	$369,815
Annual cost to Braintree for assessment for interest, sinking fund and maintenance about the year 1910,	4,103
Annual cost to Hingham for assessment for interest, sinking fund and maintenance about the year 1910,	3,919
Annual cost to Weymouth for assessment for interest, sinking fund and maintenance about the year 1910,	6,064
Extra annual cost, at about the year 1910, to South Metropolitan district of building and maintaining works for admitting these three towns,	5,554

It is possible also to dispose of the sewage of Randolph and Holbrook in connection with Braintree, Weymouth and Hingham,

and the probable cost of works for receiving and disposing of the sewage of all five towns into the Metropolitan sewer has been estimated as follows. This estimate also, like the two preceding, does not include the cost of local sewers to collect the sewage of the towns.

Total cost of works,	$665,370
Estimated annual cost to the various towns for assessment for interest, sinking fund and maintenance, at about the year 1910: —	
Braintree,	4,240
Weymouth,	6,260
Hingham,	4,052
Randolph,	1,987
Holbrook,	1,300
Extra annual cost to the South Metropolitan district, at about the year 1910, of building works and admitting these towns,	15,633

In the course of these investigations the possibility of collecting the sewage in the neighborhood of the Weymouth Back River has also been considered. If only the towns of Braintree and Weymouth should enter the system, it would probably be somewhat less expensive to the South Metropolitan district to construct works for admitting these towns, if the pumping station should be located near the Weymouth Fore River, than to construct the works near the Weymouth Back River; but if the town of Hingham should also be admitted to the district, the indications are that it might be somewhat less costly to the district to locate a pumping station near the Weymouth Back River. If the towns of Randolph and Holbrook should also be admitted, the cost might still be somewhat less if the pumping station should be located near the Weymouth Back River. The difference in cost to the towns would be very small in either case, but might be considerable in the case of the district as a whole. Either plan would be satisfactory, and the most appropriate one could be selected only after very careful study.

It will be seen from the foregoing tables that it would probably be somewhat less expensive for Randolph and Holbrook to dispose of their sewage in connection with the other towns by discharging it into the high-level sewer than to purify the sewage on land, but these towns will probably not find sewerage necessary for several years after sewers are required in Braintree and Weymouth. If Randolph and Holbrook should join the South Metropolitan district,

and works should be constructed for disposing of their sewage into the high-level sewer, an extra cost might be entailed to these towns by the necessity for making the works of sufficient size to admit them before they require sewerage, and the consequent necessity for assessing upon them a part of the cost of the works. It will be practicable for these towns to purify their sewage satisfactorily upon available lands for many years in the future, and under the circumstances it does not seem necessary or desirable to provide for the disposal of the sewage of the towns of Randolph and Holbrook into the high-level sewer.

In the cases of the other three towns sewerage will be needed before very long. It is very important to avoid locating sewer outlets close to the shores in this region where there are extensive areas of flats, and nuisances might result; but, as already indicated, it will probably be found desirable to discharge the sewage into the harbor, in order to save expense. Under the circumstances, a general system of sewerage for the three towns would probably be found of much advantage in enabling them to secure a suitable sea outlet at a reasonable cost.

It is evident that the sewage of these towns can be delivered at the proposed high-level sewer outlet without special difficulty; and it seems probable, from the investigations that have been made, that this method of disposing of the sewage of these towns will be on the whole the least expensive and most satisfactory that it is practicable to adopt.

The quantity of sewage which these towns would deliver to the high-level sewer outlet might amount, at the end of the period for which this outlet is designed to serve, to 12,000,000 gallons per day, and possibly a somewhat larger quantity. In the estimates of cost that have been given, no account has been taken of the probability that if this sewage is admitted to the high-level sewer the length of time during which that sewer would serve the district might be somewhat reduced. It is evident, however, that the capacity of the high-level sewer would not be taxed by admitting the sewage of these towns until nearly the close of the period for which it is designed to serve. The sewage from the towns in question would enter the sewer about two miles from Nut Island and three miles from its outlet, and it would be feasible to extend the force main, through which the sewage would be conveyed, to the end of the

main sewer at Nut Island when the capacity of the high-level sewer was reached, at a less cost, all things considered, than would be required if the high-level sewer should be built of larger size for the purpose of receiving the sewage of these towns in the beginning.

The outlet pipes from the end of the high-level sewer to the point of discharge will not all be laid in the beginning, so that at some future time provision could be made for the extra quantity of sewage that would be brought in by these towns if it should be found necessary to do so.

Considering the difficulty that may be encountered in securing a satisfactory system of sewage disposal for Braintree and Weymouth and probably also for Hingham, and the probability that a suitable method of disposal of the sewage may be found by discharging it through the high-level sewer and outlet, it seems proper that provision should be made to allow these towns to use this outlet in case they may choose to do so in the future, either by becoming a part of the Metropolitan district or by building and operating all the necessary works and paying a rental for the use of this portion of the Metropolitan works.

In making the investigations, studies and estimates for this report the following engineers have been engaged: —

William S. Johnson, assistant engineer of the board, in charge of special studies and the investigations as to filtration areas and the disposal of sewage of the Charles River valley.

Laurence Bradford, assistant engineer, in charge of hydrographic surveys and studies.

Charles G. Hyde, assistant engineer, in charge of the preparation of maps, plans and estimates.

Respectfully submitted,

X. H. GOODNOUGH,
Chief Engineer.

BOARD OF HEALTH

MAP OF

CHAR

ON HARBOR

s in which traces of sewage from
n Island outlets are at times visible,
ewage may be visible from proposed
ets near Peddocks Island.

April, 1900.

BO

Scale of Miles

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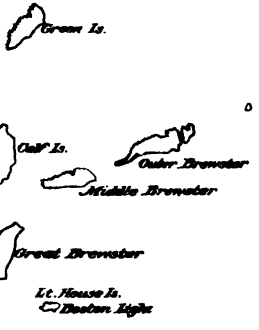

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APPENDIX.

TABLE SHOWING GROWTH OF POPULATION

[The populations from 1850 to 1900 are from the

	CITY OR TOWN.	YEAR.								
		1850.	1855.	1860.	1865.	1870.	1875.	1880.	1885.	1890.
1	East Boston, .	9,861	15,963	19,356	21,872	25,516	29,347	29,926	31,419	36,930
2	Charlestown, .	17,216	21,700	25,065	26,399	28,323	33,556	33,731	37,673	38,348
3	Somerville, .	3,540	5,806	8,025	9,353	14,685	21,868	24,933	29,971	40,152
4	Chelsea, . .	6,701	10,151	13,395	14,403	18,547	20,737	21,782	25,709	27,909
5	Everett, . .	–	–	–	–	2,220	3,651	4,159	5,825	11,068
6	Cambridge, .	15,215	20,473	26,060	29,112	39,634	47,838	52,669	59,658	70,028
7	Malden, . .	3,520	4,592	5,865	6,840	7,367	10,843	12,017	16,407	23,031
8	Medford, .	3,749	4,603	4,842	4,839	5,717	6,627	7,573	9,042	11,079
9	Winthrop, .	–	407	544	633	532	627	1,043	1,870	2,726
10	Melrose, . .	1,260	1,976	2,532	2,865	3,414	3,990	4,560	6,101	8,519
11	Arlington, .	2,202	2,670	2,681	2,760	3,261	3,906	4,100	4,673	5,629
12	Belmont, .	–	–	1,198	1,279	1,513	1,937	1,615	1,939	2,098
13	Lexington, .	1,893	2,549	2,329	2,220	2,277	2,505	2,460	2,718	3,197
14	Winchester, .	1,353	1,801	1,937	1,968	2,645	3,099	3,802	4,390	4,861
15	Woburn, .	3,956	5,448	6,287	6,999	8,560	9,568	10,931	11,750	13,499
16	Stoneham, .	2,085	2,518	3,206	3,298	4,513	4,984	4,890	5,659	6,155
17	Wakefield, .	2,407	2,758	3,207	3,244	4,135	5,349	5,547	6,060	6,982
18	Total, .	74,958	103,415	126,529	138,084	172,859	210,432	225,738	260,064	312,211

TABLE SHOWING GROWTH OF POPULATION OF THE BOSTON MAIN DRAINAGE

[The populations from 1850 to 1900 are from the

	CITY OR TOWN.	YEAR.								
		1850.	1855.	1860.	1865.	1870.	1875.	1880.	1885.	1890.
1	Boston (proper),	113,721	126,296	133,563	141,083	138,781	140,669	147,075	147,138	161,330
2	South Boston, .	13,309	16,912	24,921	29,363	39,215	54,147	56,369	61,534	66,791
3	Brighton, . .	2,356	2,895	3,375	3,854	4,967	6,200	6,693	8,523	12,032
4	Dorchester, .	7,969	8,340	9,769	10,717	12,261	15,788	17,890	20,717	29,638
5	Roxbury, . .	18,364	18,469	25,137	28,426	34,753	50,429	57,123	65,965	78,411
6	West Roxbury, .	–	4,812	6,310	6,912	8,683	11,783	14,032	17,424	24,997
7	Brookline, . .	2,516	3,737	5,164	5,262	6,650	6,675	8,057	9,196	12,103
8	Dedham, . .	4,447	5,633	6,330	7,195	7,342	5,756	6,233	6,641	7,123
9	Hyde Park, .	–	–	–	–	4,136	6,316	7,088	8,376	10,193
10	Milton, . .	2,241	2,656	2,669	2,770	2,683	2,738	3,206	3,555	4,278
11	Newton, . .	5,258	6,768	8,382	8,975	12,825	16,105	16,995	19,759	24,379
12	Quincy, . .	5,017	5,921	6,778	6,718	7,442	9,155	10,570	12,145	16,723
13	Waltham, . .	4,464	6,049	6,397	6,896	9,065	9,967	11,712	14,609	18,707
14	Watertown, .	2,837	3,578	3,270	3,779	4,326	5,099	5,426	6,238	7,073
15	Total, . .	182,499	212,066	242,065	261,950	293,129	340,827	368,469	401,820	473,778
16	Total Metropolitan Districts, .	257,457	315,481	368,594	400,034	465,988	551,259	594,207	661,884	785,989

OF THE NORTH METROPOLITAN DISTRICT.

census reports; those from 1905 to 1940 are estimated.]

YEAR.										
1895.	1900.	1905.	1910.	1915.	1920.	1925.	1930.	1935.	1940.	
42,595	45,756	52,800	60,000	67,500	75,000	83,000	91,000	99,500	108,000	1
40,304	40,652	43,700	45,200	46,800	48,300	50,000	51,700	53,300	54,800	2
52,200	61,643	74,500	86,000	97,000	108,000	118,000	128,000	138,000	147,500	3
31,264	34,072	38,000	42,100	46,200	50,600	55,200	60,000	65,000	70,000	4
18,573	24,336	31,000	39,000	47,000	55,000	63,000	71,000	79,000	87,000	5
81,643	91,886	104,000	117,000	131,000	145,000	160,000	175,000	190,000	206,000	6
29,708	33,664	40,500	47,000	54,500	62,000	69,800	78,000	86,500	95,500	7
14,474	18,244	25,000	32,000	39,500	47,500	56,500	66,500	75,500	85,000	8
4,192	6,058	7,700	9,900	12,300	15,000	18,000	21,400	25,000	29,000	9
11,965	12,962	16,300	20,000	23,900	28,100	32,700	37,800	43,500	49,900	10
6,515	8,603	9,700	11,800	14,400	17,500	21,300	25,600	30,500	36,000	11
2,843	3,929	6,000	8,100	10,800	13,800	17,300	21,300	25,900	30,700	12
3,496	3,831	4,500	5,400	6,600	8,100	9,900	11,800	13,800	15,900	13
6,150	7,248	9,500	12,000	14,800	18,100	22,000	26,000	30,200	34,600	14
14,178	14,254	16,300	18,100	20,000	22,100	24,200	26,400	28,800	31,900	15
6,284	6,197	7,000	8,000	9,300	11,100	13,200	15,600	18,200	21,100	16
8,304	9,290	10,900	12,900	15,200	17,800	20,800	24,200	28,000	32,200	17
374,688	422,625	497,400	574,500	656,800	743,000	834,900	931,300	1,030,500	1,135,100	18

DISTRICT AND THE METROPOLITAN DISTRICTS CONNECTED THEREWITH.

census reports; those from 1905 to 1940 are estimated.*]

YEAR.										
1895.	1900.	1905.	1910.	1915.	1920.	1925.	1930.	1935.	1940.	
160,349	164,000*	169,000	174,000	178,000	182,000	186,000	190,000	194,000	198,000	1
67,903	70,000*	73,500	76,000	79,500	83,000	87,000	91,000	95,000	99,000	2
15,001	19,279	24,000	30,000	36,000	42,000	49,000	56,000	64,000	72,000	3
45,909	61,000*	80,000	101,000	122,000	144,000	167,000	191,000	216,000	241,000	4
92,088	107,000*	120,000	133,000	145,000	156,000	166,000	176,000	184,000	192,000	5
32,761	45,000*	61,000	77,000	94,000	113,000	132,000	152,000	172,000	192,000	6
16,164	19,935	26,000	33,000	40,000	47,000	54,000	62,000	70,000	79,000	7
7,211	7,457	9,000	11,000	13,500	16,000	19,500	23,500	27,500	32,000	8
11,826	13,244	14,700	16,500	18,600	21,000	23,800	26,900	30,300	34,000	9
5,518	6,578	8,600	11,100	14,600	19,100	24,600	30,600	37,100	44,000	10
27,590	33,587	42,000	53,000	66,000	80,000	95,000	111,000	127,000	144,000	11
20,712	23,899	28,200	33,700	40,000	47,200	55,500	65,000	75,800	88,000	12
20,876	23,481	27,000	31,500	37,500	44,500	52,500	61,500	71,500	82,000	13
7,788	9,706	12,000	14,500	17,500	21,000	25,500	30,500	36,000	42,000	14
581,696	604,166	695,000	795,300	902,200	1,015,800	1,137,400	1,267,000	1,400,200	1,539,000	15
906,384	1,026,791	1,192,400	1,369,800	1,559,000	1,758,800	1,972,300	2,198,300	2,430,700	2,674,100	16

* The population for 1900 of Boston (proper) South Boston, Dorchester, Roxbury and West Roxbury is an estimate.

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Eng 1109.00
Report of the State Board of Health
Cabot Science 003163721
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